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PLANMKT: An Exploratory Model of the Market Mechanism in a Planned Economy

Robinson, J.M.

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PLANMKT: AN EXPLORATORY MODEL OF THE MARKET MECHANISM IN A PLANNED ECONOMY

Jennifer M. Robinson

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

One research activity in the Management and Technology Area Task on Technological Innovation has been investigation of the process of technological substitution using the system dynamics modeling technique. This work has produced TECH1, a model that looks at technological substitution as the outcome of market competition between an old and a new technology in a system in which production efficiency and product quallity improve through learning processes. (As documented in IIASA WP-79-104, WP-79-105 and WP-79-106.)

TECH1 clearly assumes a market economy. In the model, price is continuously adjusted according to the balance of supply and demand, and investment occurs on the basis of returns on capacity, without reference to planning targets. Recognition of TECH1's market economy orientation leads naturally to the question, "How much does the model's behavior depend on the market economy assumptions? How would model outcomes be different if the mechanisms used had been more descriptive of a planned economy.

This working paper presents the first stage of research on these questions. Both for ease of construction and testing, and because the question of representing a planned market market mechanism is of interest in and of itself, our work on dynamic modeling of technological substitution in a planned economy context began by with construction of a model of capacity formation and marketing in a planned economy. The model, PLANMKT, was formulated to be comparable to the analagous mechanism used in TECH1 for the market economy case. It is intended that PLANMKT will eventually be used as a base for looking at technological substitution within a planned economy system.

PLANMKT, at this point, is a tentative and theoretical formulation. It has been tested for internal consistancy, but it has not undergone either testing using real data or careful examination and criticism by experts on planned market operation. This working paper is presented as a means of opening the model to scrutiny and criticism by persons knowlegable about the system it describes. It is hoped that such criticims can lead to further work that will be useful and interesting both to economists interested in the planned market case and to those interested in the increasingly large portion of market economies that operates under some form of state control and planning.

TABLE OF CONTENTS

INTRODUCTION 1

Methodology 1

STRUCTURE 2

Representing a Planned Economy Market Structure 3

BEHAVIOR 5

Potential Tests 5
Policy Variables 7
Structural Parameters 8
General Behavior Trends 8
Environmental Conditions 10

POLICY TESTS 13

Inventory Tolerance Policies 16
Adjustment Speed Policies 19
General Remarks on Policy Tests 22

APPENDIX A: ANNOTATED BIBLIOGRAPHY ON SYSTEM DYNAMICS 23
APPENDIX B: DOCUMENTED PROGRAM LISTING 24

PLANMKT:AN EXPLORATORY MODEL OF THE MARKET MECHANISM IN A PLANNED ECONOMY

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INTRODUCTION

The following paper describes PLANMKT, a simple, general model of the market mechanism in a planned economy. The paper and the model are exploratory. The paper's purpose is to describe the model and its behavior and to ask where they are and are not reasonable. It begins with a description of model structure and proceeds to description of the behavior that eminates from that structure.

Methodology

PLANMKT is a system dynamics model, following the methodology developed by Jay Forrester and others at MIT. Basically this means that it represents the system being modeled as a set of state variables whose rates of change are regulated by nonlinear information flows. It also implies an attitude toward modeling which:

- puts more emphasis on structure, and on the relationship between structure and behavior, than in parametric precision,

- views structure in terms of state variables, feedback and nonlinearities, and

- emphasizes that model validity should be assessed by reasonableness and insight-generating ability of model structure and behavior.

For a fuller description of system dynamics the reader should refer to the sources listed in Appendix A.

STRUCTURE

People tend to think that markets operate very differently in planned economies than in a market economies. From a conventional economic perspective they do. Many operators are changed, to say nothing of the terminology used to describe operators. State plans and goals determine investment and price. One can't assume profit-maximizing firms. The meaning of supply curves becomes dubious, and hence, even though demand may still follow downward sloping curves, equilibrium prices cannot be calculated.

Cybernetically, however, the differences are not all that large. As shown in Figure 1, in both systems information about the state of the system is utilized in making decisions concerning price adjustments and resurce allocation (including investment) decisions*. In both systems adjustment decisions strive to maintain some balance between supply and demand. In both systems demand can be decreased through increases in price and supply can be varied in the short term by varying capacity utilization and in the long term by altering investment. In both systems overproduction leads to excess inventories and underproduction leads to depleted inventories, perhaps accompanied by long waiting times for product delivery.

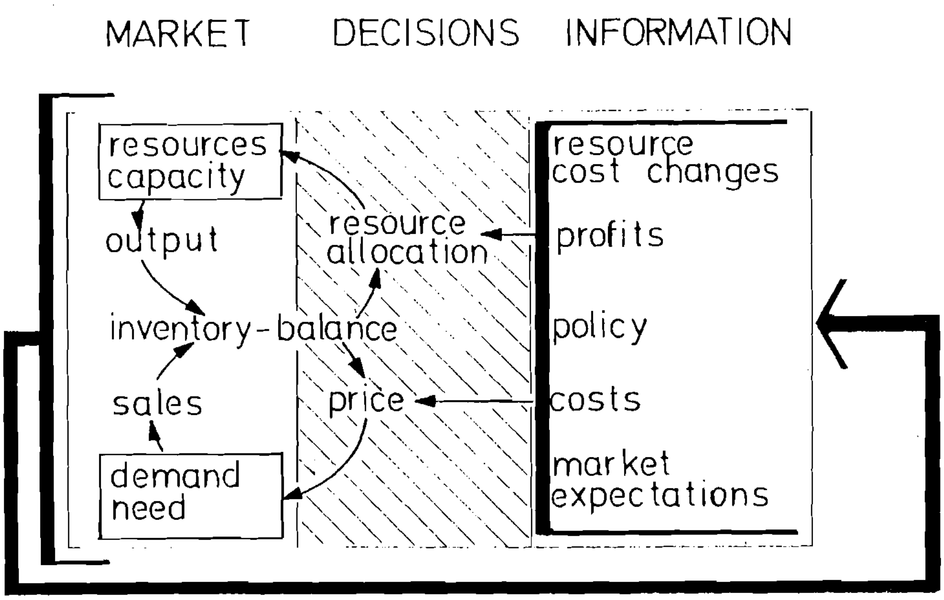

Figure 1: Common structure of free and planned market mechanisms.

Behaviorally, too, there are similarities. Neither operates perfectly; both are prone to fluctuations, to alternation between overstocked and understocked shelves; on the whole the planned system tends to seek a dynamic balance with a tendency toward under, rather than over-supply; however this tendency varies greatly between products.

The major differences seem to be that the planned economy places greater emphasis on politically determined goals, makes price and investments adjustments only occasionally, and tends to make large adjustments when adjustments are made, while the market economy adjusts more or less continuously, steering toward profits rather than politically determined targets.

* I find that what I would call investment decisions are often called resource allocation decisions by planned market economists. In the following text the word investment will often be used to designate the producer's resource allocation decisions.

Representing a Planned Economy Market Structure

As just stated, price and investment levels of planned economies tend to change more slowly than those of market economies because adjustments require deliberate decisions by planners. In most market models price and investment vary continuously with market conditions. To convert the conventional market model to better describe a planned economy I have assumed price and investment are state variables and are adjusted periodically by rather large steps when system conditions imply an unsatisfactory balance of supply and demand.

But which conditions? On what information are adjustments based? In practice this probably depends on the social, technical and economic characteristics of the product in question. For export products, profitability factors are probably relatively important; profitability draws investment, prices are set as high above costs as international competition will bear. For health-related goods and services, such as milk, fresh vegetables and sports and recreation, prices and investment may be managed in order to keep per capita consumption to target levels. For other goods, adjustments may take place because symptoms of short supply, such as long waiting lines and long delivery delays, become disruptive or because symptoms of oversupply, in particular, the accumulation of large inventories.

PLANMKT assumes the latter, inventory controlled, case. Figure 2 shows the price mechanism assumed. Price is a state variable. It is increased by an exogenously set percentage when inventories become so backlogged that waiting times exceed tolerance thresholds. It is assumed that planners will utilize the price mechanism less when prices have become very high and where further price increases will not have much influence on quantities demanded. (This mechanism has been added because without it prices have, in some simulations, increased a million fold under conditions of persistent inventory backlogs.)

Price level is decreased, again by an exogenously set percentage, if inventories become overly large. The target for inventory size is determined by an exponential averaging of past sales called expected sales (thus introducing an assumption that sales expectations are based on past sales). When actual inventories exceed expected sales by more than the tolerated amount, price is increased by an exogenously set percentage. In the form of the model shown here, constants are used for all the exogenous adjustment coefficients mentioned. If information were available about the likely behavior of these coefficients over time they could either be converted to exogenous variables or endogenized.

Figure 3 shows how investment is modeled. The central assumption behind this formulation is that planners base investment decisions on the difference between actual and target capacity. Target capacity is increased by some percentage of present capacity when inventories fall below threshold values and is decreased when market coverage exceeds tolerance thresholds.

The formulation gains extra terms because I have assumed that planners, in comparing actual to target capacity, also take into account recent investments which have not yet come on line (investments in progress, xiip). The formulation also assumes that in accounting for investments in progress planners will distinguish between investments needed to replace depreciation and those leading to capacity expansion.

I am told (verbal communication,H.D. Haustein) that in practice at least in the German Democratic Republic, price adjustments take place only rarely, and require the action of very high level planners; but that investment adjustments occur rather frequently, and may be made in a relatively decentralized fashion. This distinction has been represented rather crudely in PLANMKT by making the threshold values at which price increases occur higher by a factor of 2 to 3 than those at which production targets are adjusted upwards. It would be more desirable to permit price adjustments only every N years (where N typically is around 5) and permit production target adjustments every N months. However, that would be a much more complex formulation given the software I am using.

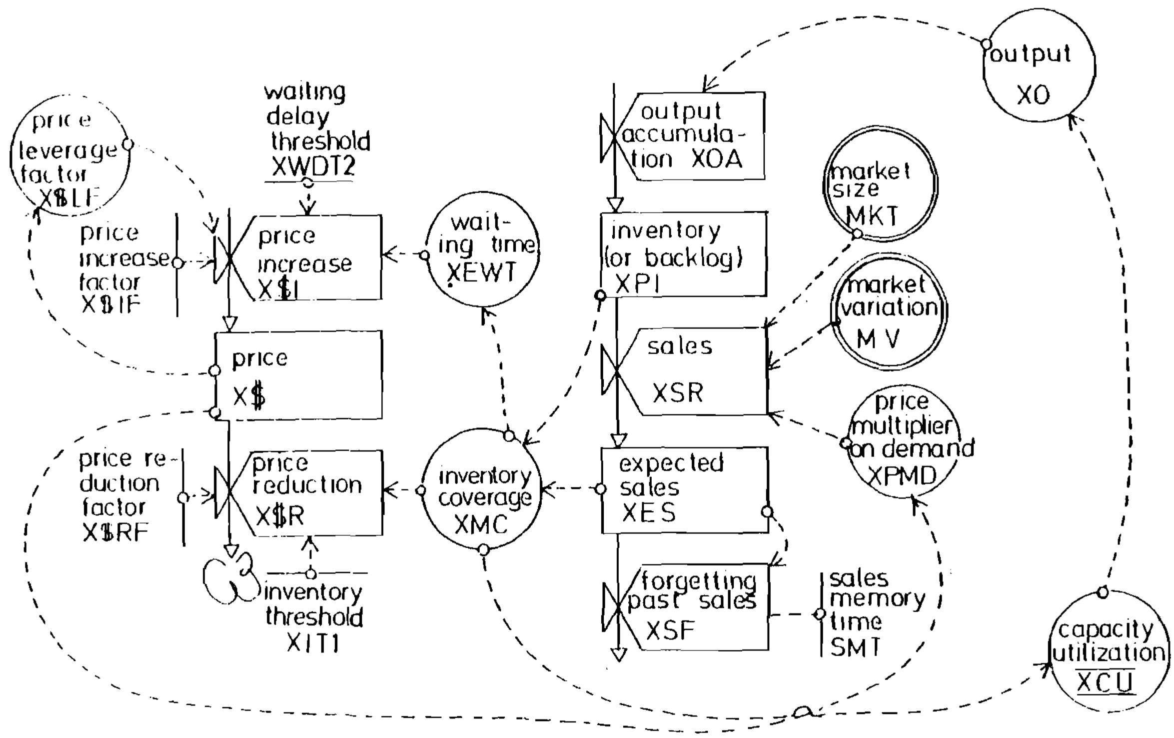

Figure 2. Flow diagram for PLANMKT price mechanism. Rectangles represent state variables, valves represent rates of change, single bounded circles represent auxiliaries--instantaneously changing information variables that regulate rates of change--double bounded circles represent exogenously changing variables and line segments represent constants. Solid connecting lines represent real flows; dotted connecting lines represent information flows.

One other mechanism can adjust supply. Capacity utilization may rise or fall according to inventory levels. Unlike price and investment decisions, capacity utilization is assumed to vary continuously and may shift by relatively small increments. In test runs it is assumed that capacity utilization can vary anywhere from zero to one hundered percent. Alternate assumptions can be tested by changing model parameters.

Logically enough, investment, after a delay for construction and start up operations, leads to increased capacity thus to increased supply. Increased prices--because price elasticity of demand presumably holds in a planned economy--lead to decreased sales. The model can be parameterized for different delay times and different price elasticities of demand according to the product's nature.

Finally, demand is subject to an underlying modal trend--either growth or decline--upon which is superimposed random variation.

When all these factors are combined the resulting structure is as shown in Figure 4.

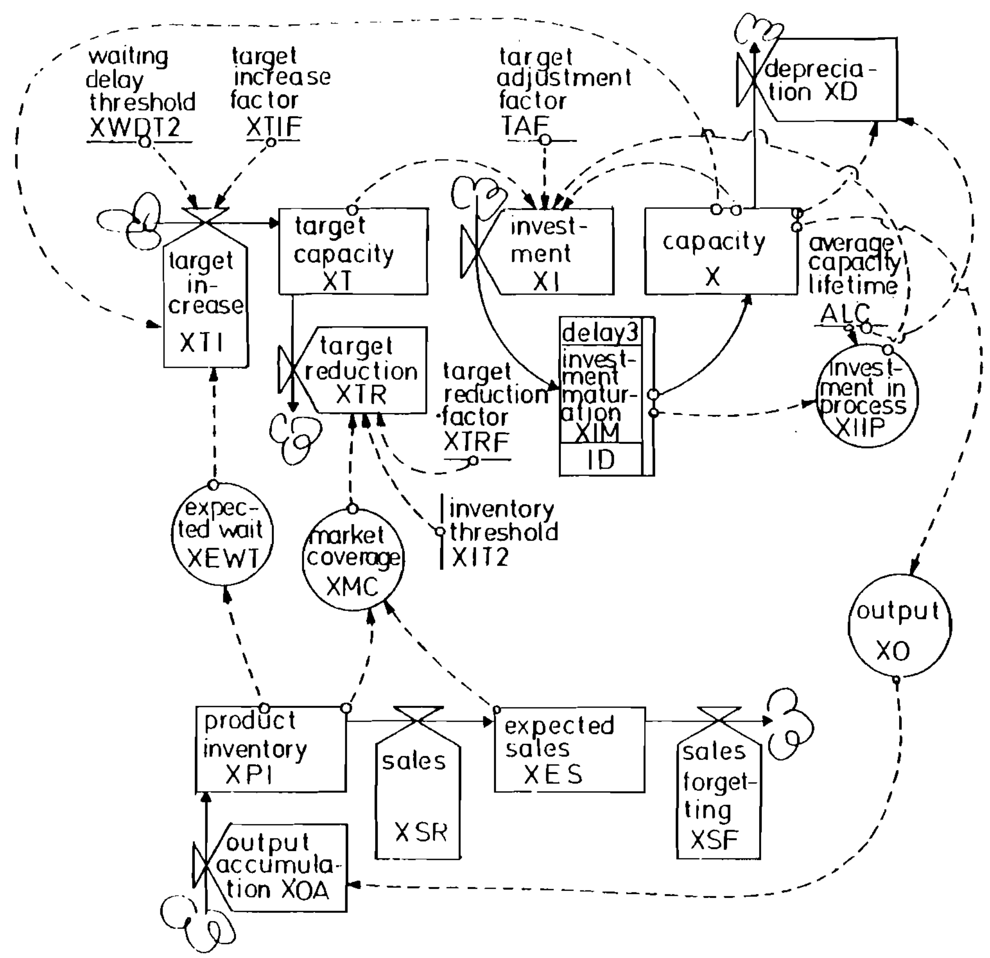

Figure 3: Investment structure used in PLANMKT

BEHAVIOR

Potential Tests

In the previous text several adjustment coefficients have been mentioned. Most of these can be regarded as policy variables, that is, as factors on which planners actively or passively make decisions. In addition PLANMKT contains several functional relationships and constants (e.g. price elasticities of demand) that differ for different commodities. At present guessed parameters in what seem to be realistic ranges are used for all these variables.

In the text below policy and structural coefficients are first listed, along with the values assumed in the base case run. Then the model's behavior in the base case run and a few variants of it are discussed. It is clearly impractical to present sensitivity tests on showing the behavior of each of the twenty-some coefficients in PLANMKT; first because the amount of work (and paper) involved would be enormous. Second because the results would be boring. Anyone interested in any particular set of tests is encouraged to run them himself. (The NDTRAN2/DYNAMO program for PLANMKT is presented in Appendix B.)

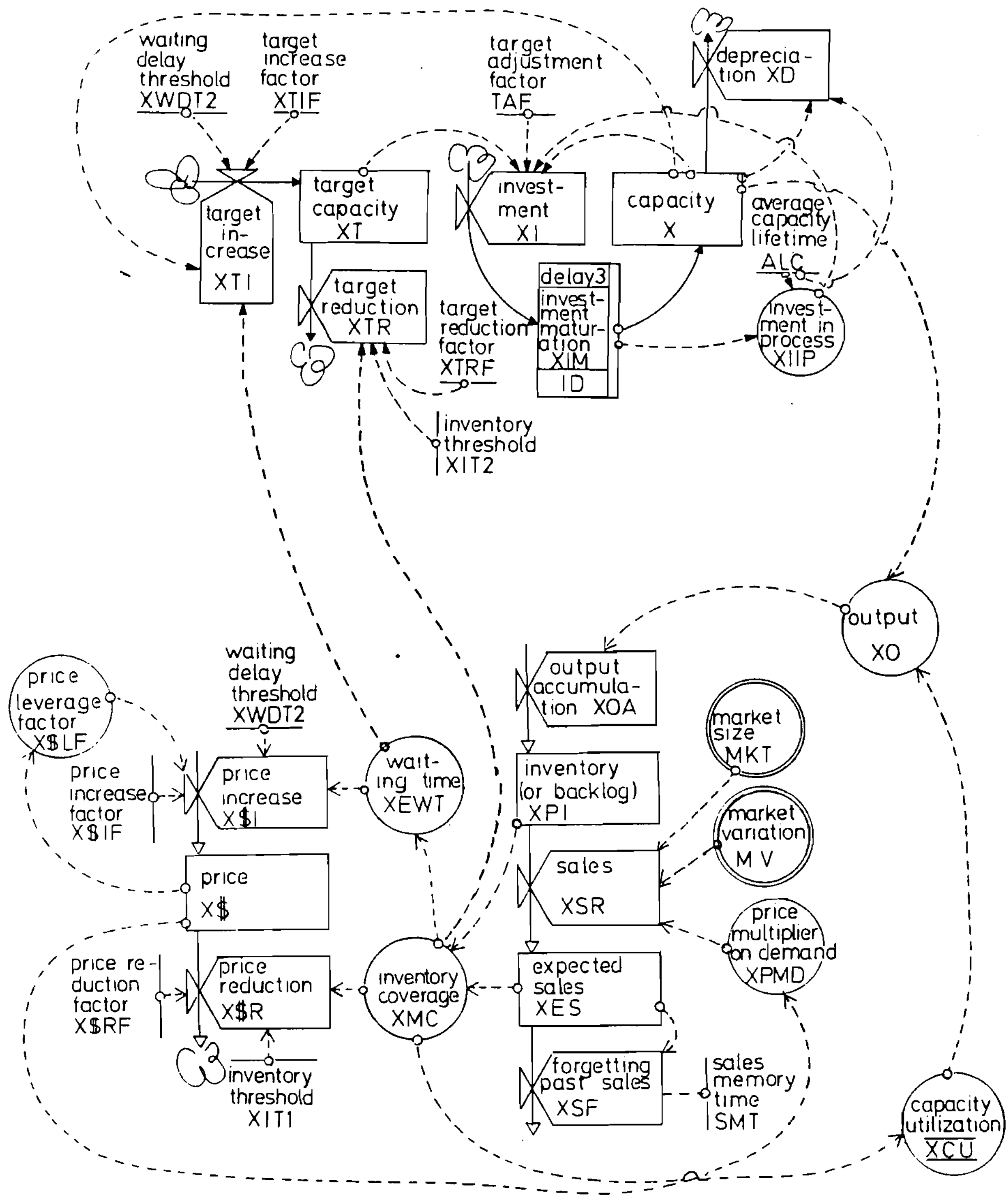

Figure 4. Dynamic structure of PLANMKT.

Policy Variables

The following variables can be altered in PLANMKT to describe different policy responses:

1. xwdt1 and xwdt2--waiting delay thresholds for price (xwdt1) and target capacity (xwdt2) adjustment. When inventory backlogs get so large that waiting times exceed the tolerance thresholds (measured here in months), price and target capacity adjustements go into effect. xwdt1=15, xwdt2=6

2. xtif--target increase factor: sets the percentage of capacity by which target capacity level is increased when xwdt2 is exceeded. xtif=0.10 (10 percent)

3. x$if--price increase factor. Sets the factor by which price levels are increased when xwdt1 is exceeded. x$if=1.5

4. xit1 and xit2--inventories thresholds for price (xti1) and target capacity (xit2) decreases. When the ratio of inventory to annual expected sales (market coverage, xmc) exceeds these figures, production is deemed excessive and price and target capacity are adjusted downward. xit1=1.0, xit2=1.0

5. x$rf--price reduction factor: percentage by which price level is decreased when inventories exceed upper threshold (xit1). x$rf=0.5

6. xtrf--target reduction factor: percentage by which target capacity is decreased when inventory exceeds upper threshold (xit2). xtrf=0.05

7. seft--sales expectation time: sample period over which sales expectations are formed. If, for example, seft=5, sales expectations are based on the sales records over the past 5 years, with a weighting that emphasizes recent years. seft=5

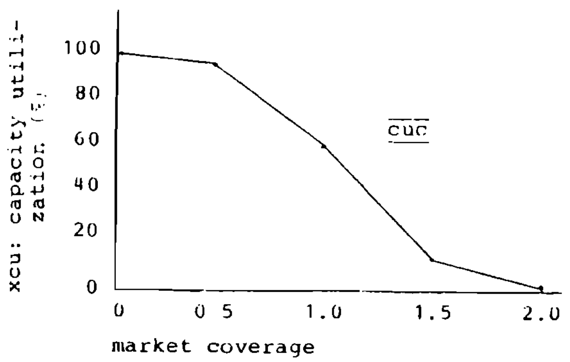

Figure 5a: Capacity utilization curve

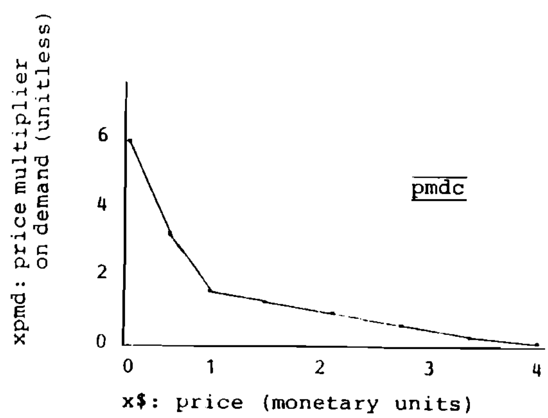

Figure 5b: Quantities demanded curve

Figures 5a and 5b: Functional forms assumed for capacity utilization (5a) and quantities demanded as a function of price (5b).

Structural Parameters

The following parameters should be adjusted to fit the model to specific commodities and specific market situations:

1. alc--average lifetime of capacity (in years); determines depreciation rate. alc=15

2. xid--investment maturation delay; number of years between the time an investment is made and new production capacity comes on line. xid=2

3. cuc--capacity utilization curve (in percent); sets capacity utilization rate as a function of market coverage (market coverage is defined as the ratio of inventory to expected sales). Curve as shown in Figure 5a.

4. mgr--market growth rate (percent per annum). Sets the rate at which the quantity of product demanded would grow if price remained constant. mgr=.03

5. msd--market standard deviation; sets the standard deviation of the normally distributed noise parameter affecting sales. msd=0.1 with mean of 1

6. pmdc--price multiplier on demand curve (in percent); increases and decreases demand as a function of price. Curve as shown in Figure 5b.

General Behavior Trends

Figures 6a and 6b show an 80 year simulation run of PLANMKT. Figure 6a shows the behavior of capacity, target capacity and inventory; Figure 6b shows the behavior of price, expected waiting time sales and market size.

The two figures reveal that the system tends to manifests slow, convergent oscillations. Over the 80 year period there are two phases where targets and investment do not expanded fast enough to keep supply up with demand. This results in inventory backlogs and lengthened waiting times for product delivery. Long waiting times lead to adjustments, first of production targets and investment, and second, of price. The condition of backordered supply persists over much of the simulated period, although the system is able to prevent expected waiting time from ever going over 18 months.

In Figure 6b it may be observed that sales behaves eratically, but tends to keep pace with market growth. One should not make much of sales variation, as it is the consequence of a random fluxuation imposed on the model's demand term. (Demand is multiplied by a number with a mean of 1 and a standard deviation of 10 percent.) Thus it is far more significant that random sales variation is absorbed by the system than that sales behave randomly. This feature of the system merits further attention. I am under the impression that the market economy market formulation might amplify rather than mitigating sales variability. It may turn out that the market mechanisms of a planned economy (at least that in PLANMKT) are simply better buffered against unpredictable consumer behavior than are their market economy equivalent.

It is interesting that the system eventually stabilizes in a behavior mode that doesn't use the price mechanism. Beginning at year 42 inventories go negative and waiting time for product delivery begins to lengthen. This leads to upward adjustment of production targets and leads to increased investment. In time the inventory backlog begins to diminish.

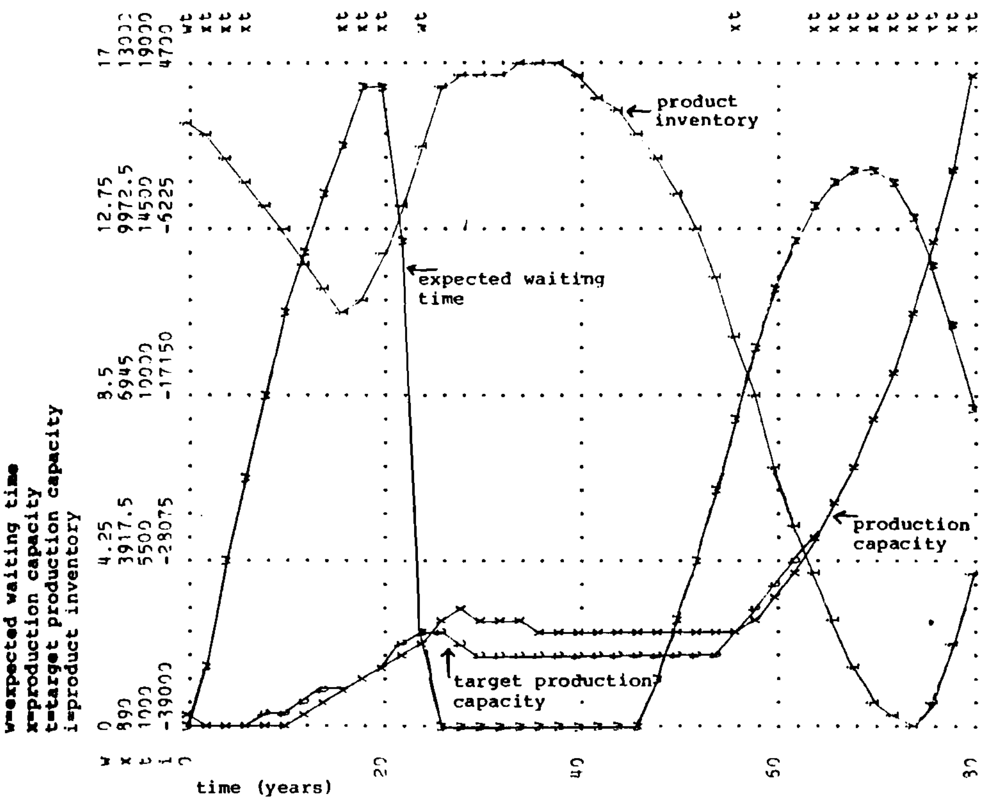

Figure 6a. Expected waiting time, production capacity, target production capacity, and product inventory.

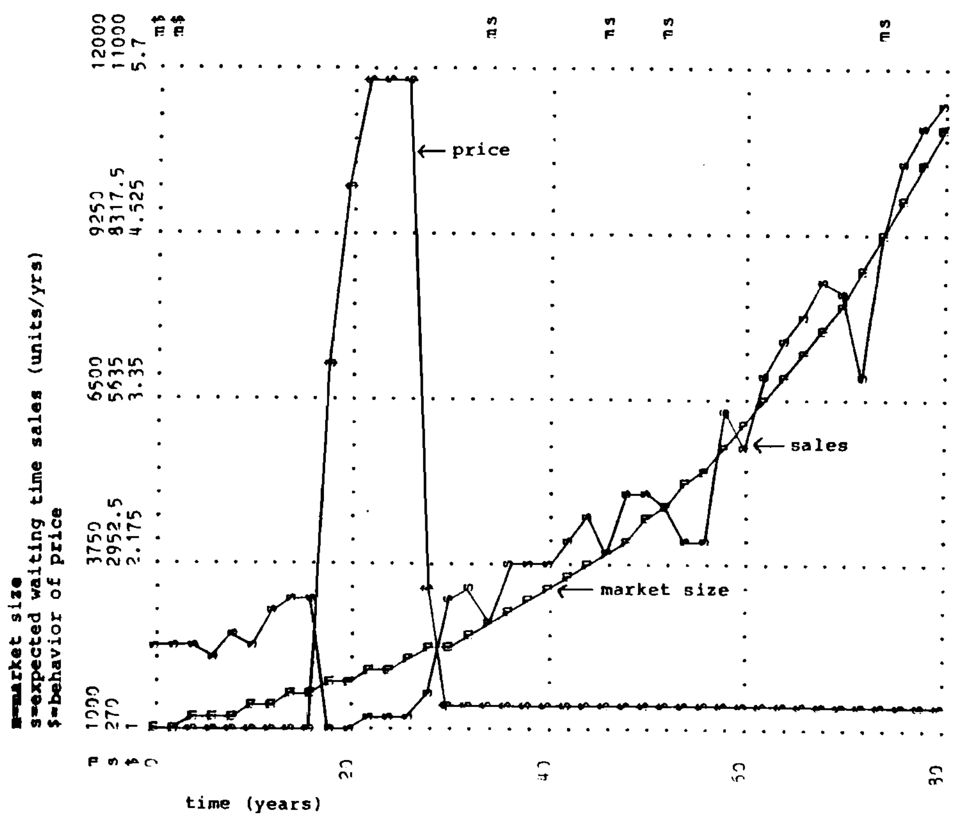

Figure 6b. Price, market size, and sales.

Figures 6a and 6b. Behaviors of key variables in 60 year base case simulation.

Environmental Conditions

Below the system's response to environmental conditions is illustrated with analyses of its behavior under different rates of market growth and different delay lengths for capacity expansion. Tests not described here show that the system is extremely good at damping out increases in the variability of demand (msd), and that it may or may not be sensitive to changes in the response of capacity utilization to market coverage (cuc), price elasticity of demand (pmdc) and the average lifetime of capacity, depending on the magnitude of the changes made and the way the system is tuned. For example, system's sensitivity to price elasticity of demand (obviously) depends on whether and how it employs the price mechanism; likewise, its sensitivity to rates of depreciation differs according to whether or not it responds rapidly to evidence of supply shortfall.

Market growth: Growth of market demand varies greatly between commodities. Figures 7a, 7b, 7c and 7d compare the respective behaviors of capacity, expected waiting time, inventory and price at four different rates of market growth. In these plots, the four rates tested, and the scenario numbers used to stand for them are:

scenario	*market growth rate*
1	5 percent per year
2 (base case)	3 " " "
3	1 " " "
4	0 " " "

(Note that the high growth scenario is quite unrealistic--few commodities have been able to maintain a 5 percent annual rate of demand increase for 80 years, especially not under circumstances of low population growth, as seen in most planned economies.)

To interpret the plots, I recommend taking one scenario and looking at the behavior of all three variables; then iterating the procedure for the other scenarios, and then comparing the results. By this means you may observe that while the system is basically stable under all four market growth scenarios it faces larger inventory and greater problems with large order backlogs under the higher growth scenarios. This results in two instances of major price increases for the 5 percent growth case and one incidence for the 3 percent case. The slow growth scenarios, on the other hand put through minor price decreases (which put them off scale on the DYNAMO plots) in about the 35th year of simulation. In neither high growth scenario does the waiting time ever exceed 20 months, and in both cases the system progressively decreases the peak waiting time at each long term inventory swing.

It is also interesting that faster growth seems to result in faster inventory oscillations. For example, in Figures 7b and 7c, scenario 1, the 5 percent growth case, reaches its first waiting delay peak and inventory trough a few years earlier than the three percent growth case, which in turn reaches its first trough a few years before the 1 percent case.

In the two slow growth scenarios, price adjustments are little used and those that take place are minor. Furthermore, in both the 1 percent demand growth and the constant demand scenarios, the system stabilizes at about the 30th year of simulation with positive inventories, and hence zero waiting time for product deliveries.

Delay Time: Another property that varies greatly between products is the amount of time required to expand capacity. For example, it may be possible to set up a new shop for assembly of electronic equipment in a few months, while construction of a new nuclear power station will generally take several years. Within the structure of PLANMKT, lengthening the capacity expansion delay time results in increasing the time required to correct an intolerable supply deficit though investment. This, in turn, causes lengthened expected waiting times and may force more frequent utilization of the price mechanism.

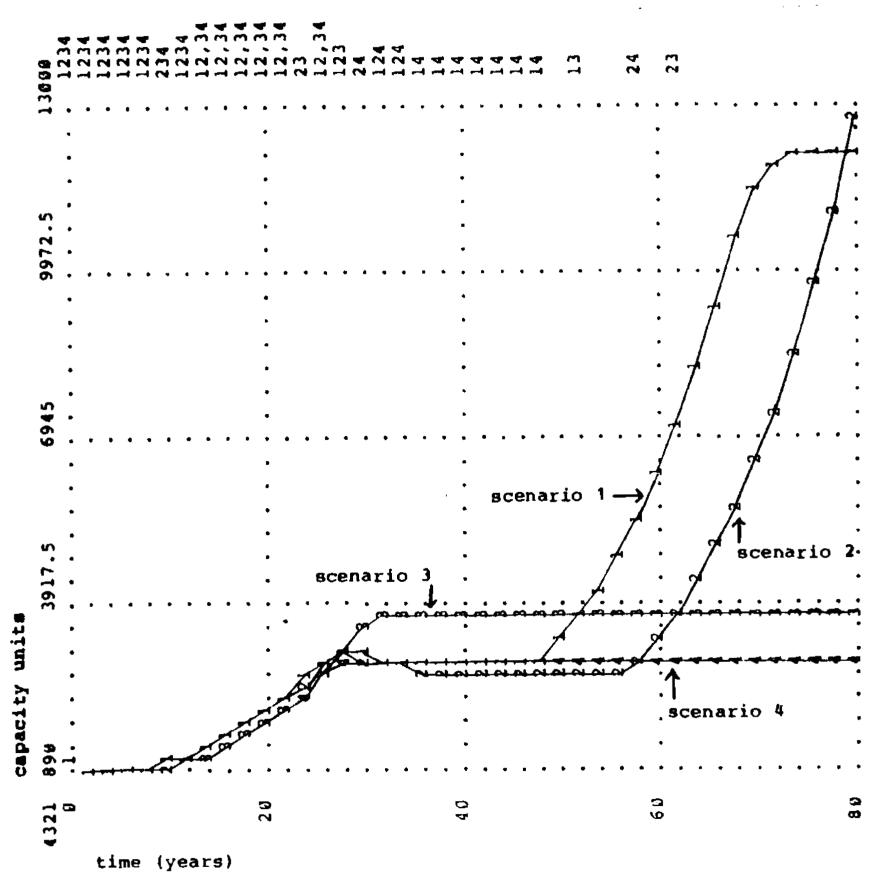

Figure 7a. Production capacities.

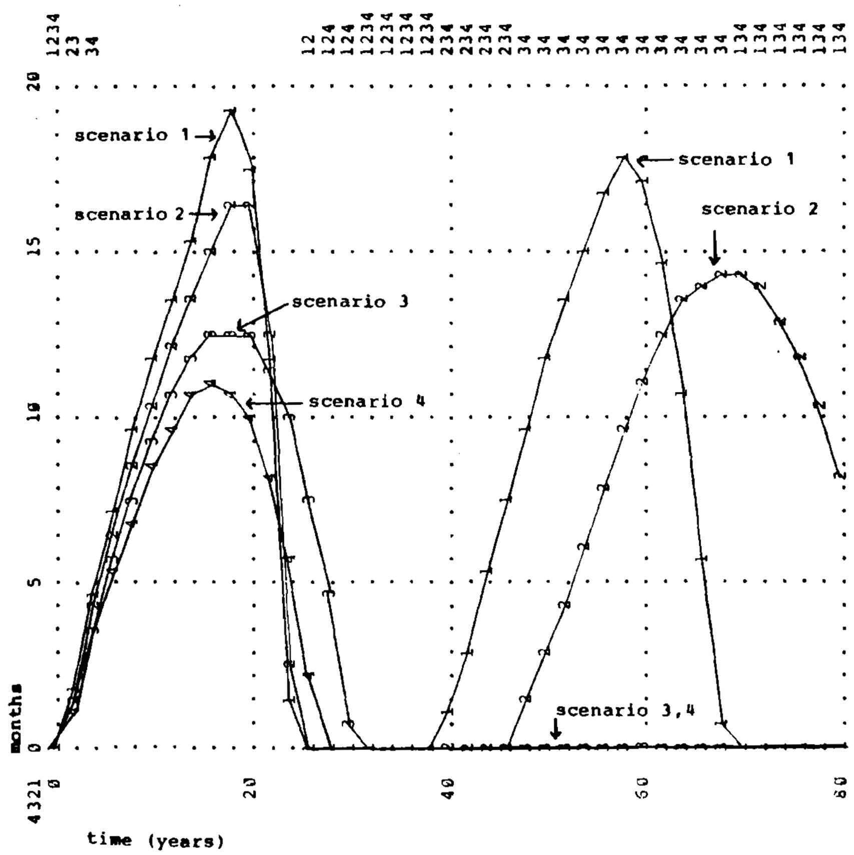

Figure 7b. Expected waiting time.

Figures 7a-d. Comparison of key variables under four different market growth scenarios.

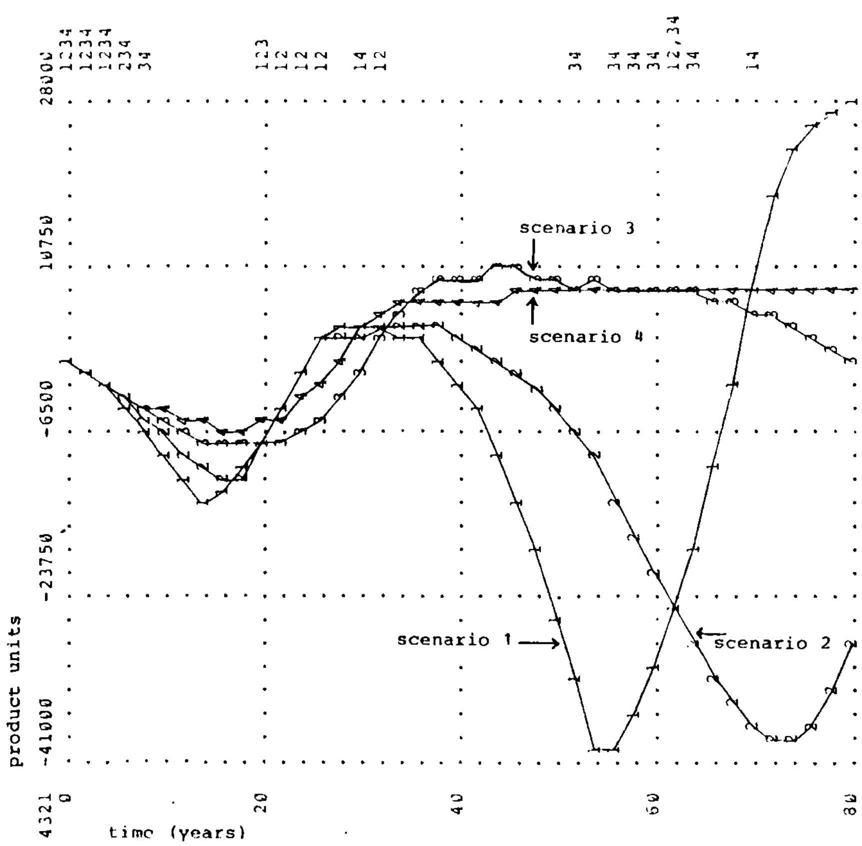

Figure 7c. Product inventories.

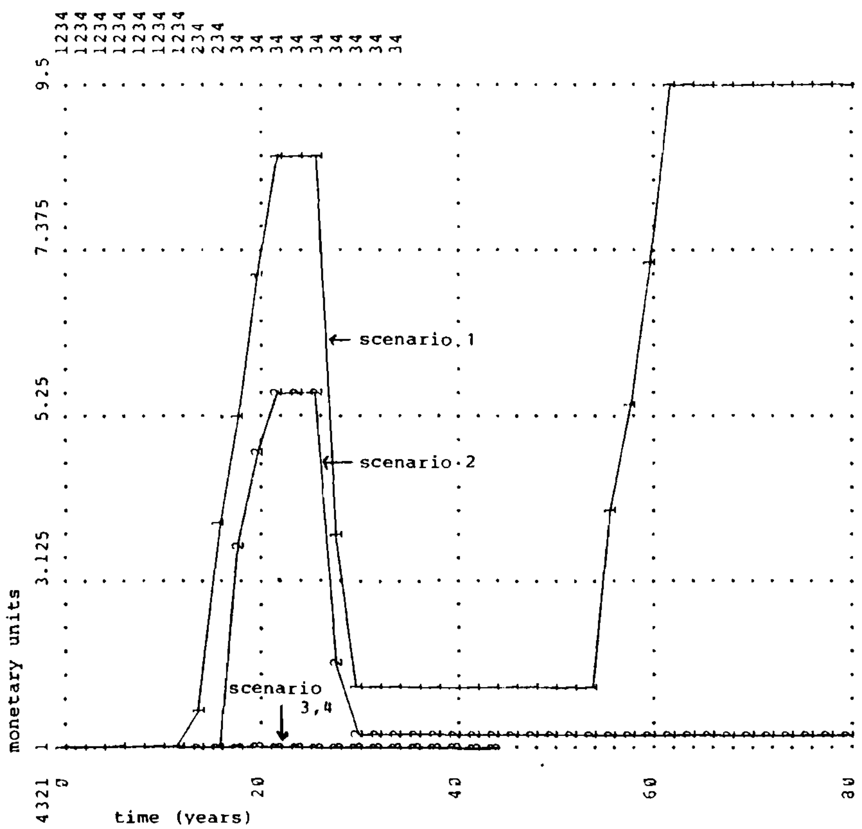

Figure 7d. Prices.

Figures 8a, 8b, 8c and 8d contrast the behaviors of capacity, expected waiting time, inventory and price for capacity expansion. Delay lengths correspond to plot numbers as follows:

scenario	*capacity expansion delay length*
1	5 years
2 (base case)	2 "
3	1 "

As shown in the plots, the system behaves contrary to expectation in one respect: the longer the delay time, the less the inventory fluctuation and the more gradual the adjustment to conditions of long waits. The difference in behavior stems from the difference in use of the price mechanism. The longer the capacity expansion delays, the longer waiting times become (8b), the higher prices are driven (8d), the more demand is driven downward, and the more rapidly the system moves into a condition of positive inventories and zero waiting time (8b). Because the price mechanism does not assist investment in stabilizing the system in scenario 3, it has has much greater inventory swings (8c -- note, 3 goes off the map in this figure).

In other words, the squeaky wheel--the case that shows the most obvious difficulties--gets greased; and frequent greasing may lead to better overall performance.

I leave it to others to ascertain this finding's realism. Do, in reality, products with longer capacity expansion delays sometimes turn out to be more stable in planned economies than products with shorter delays? It would not surprise me if they did; however, I suspect the mechanism involved might be much more general than that observed in the above tests: that products for which plant expansion is slow are generally more capital intensive and more expensive; thus they probably receive greater attention from planners than relatively cheap and easy products, and hence (presuming that more adjustent and more planning does stabilize a product's behavior) they should be more stable.

POLICY TESTS

PLANMKT is an inventory controlled system. Its self-regulating mechanisms operate to keep inventories within certain tolerance thresholds. First investment and second, in more extreme cases, prices are adjusted when those bounds are overstepped. The threshold indices used are positive inventories, which policy makers are assumed to attempt to keep to a given fraction of expected annual sales, and inventory backlogs (negative inventories), which they are assumed to try to keep sufficiently low that the waiting times for product delivery do not become unacceptably long.

Two sorts of changes can be employed within this set-up; those which alter the thresholds within which inventory movement is tolerated before corrective actions are taken and those which alter the strength of the actions taken when inventories go beyond tolerance thresholds. For example, a policy maker who felt that current investment practices were not producing the desired results might either lower (or raise) tolerance thresholds or increase (or decrease) the size of the adjustment made when thresholds are overstepped--or both.

The two sets of policy tests described below explore, respectively, the consequences of altering boundary locations and altering the extent to which capacity targets (which control investment) and prices are adjusted when the system goes beyond tolerance thresholds.

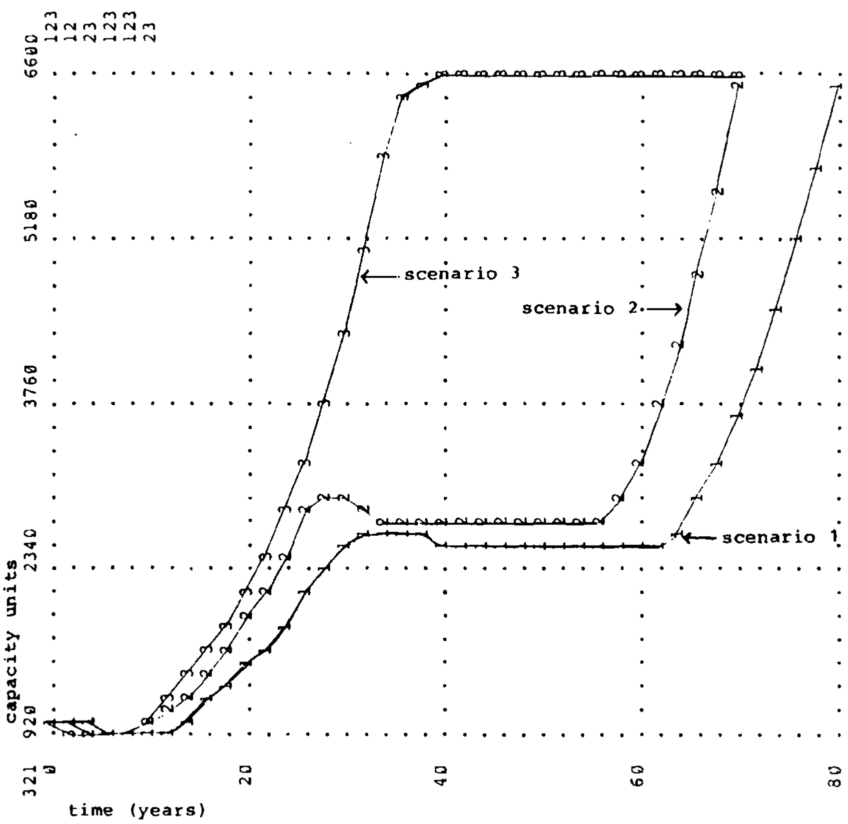

Figure 8a. Production capacities.

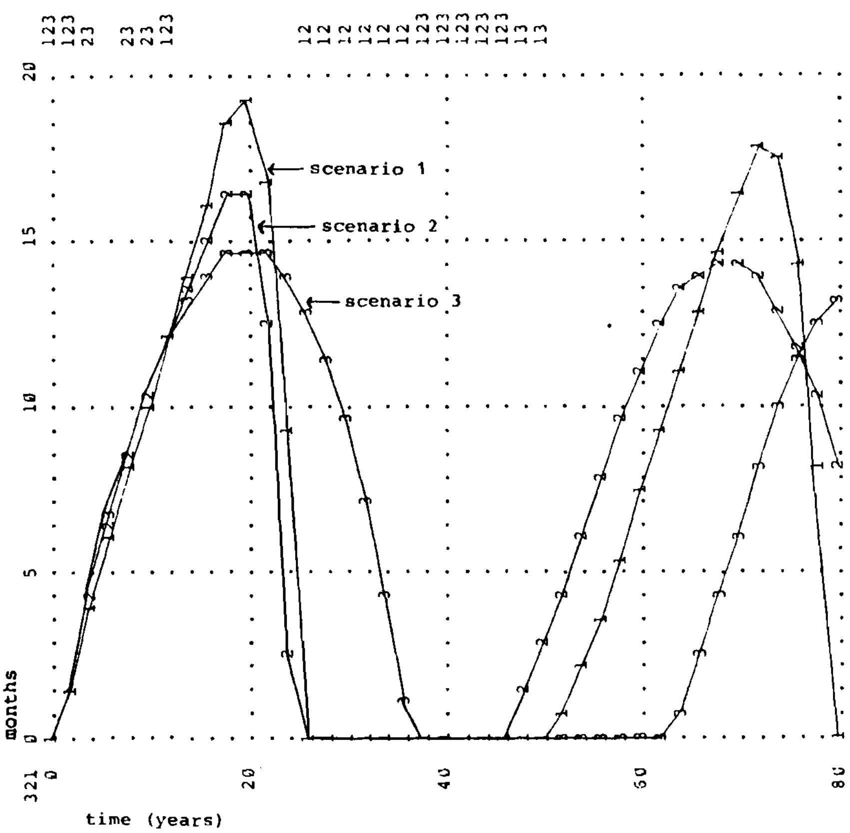

Figure 8b. Expected waiting time.

Figures 8a-d. Comparison of key variables under three different delay length scenarios.

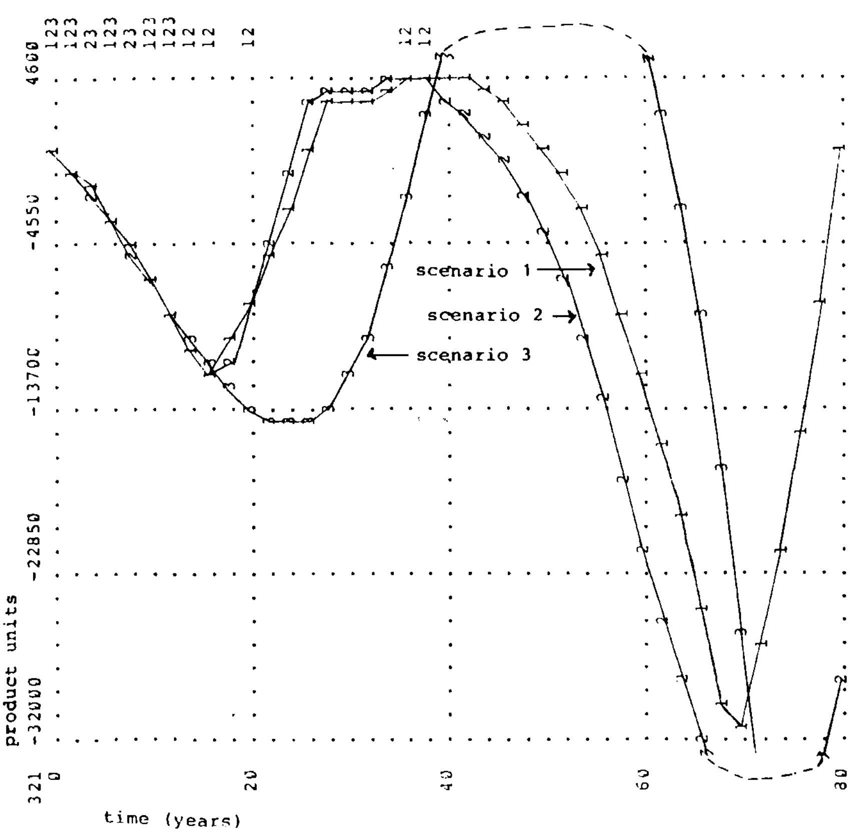

Figure 8c. Product inventories.

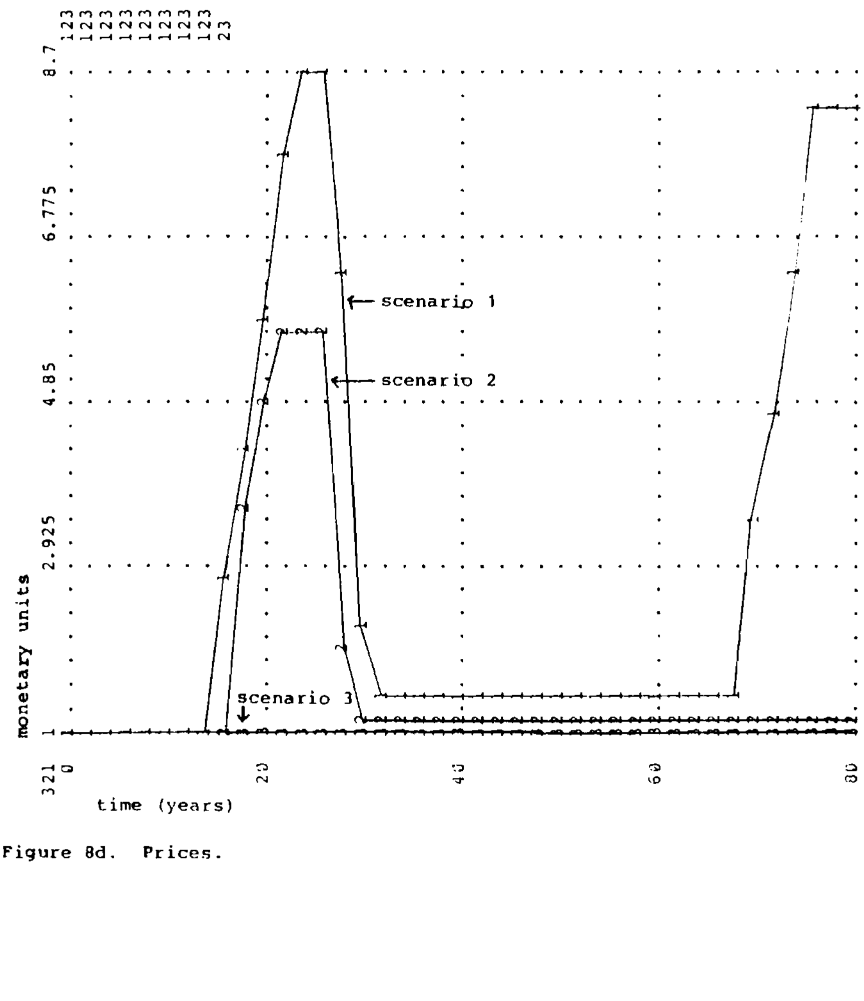

Figure 8d. Prices.

Inventory Tolerance Policies

Figures 9a, 9b, 9c and 9d show the effects of alternately doubling and halving the values of inventory and waiting delay thresholds. As in Figures 7a, 7b, 7c and 7d these use a comparative plot format, with the base case plot labelled with the number 1 and other scenarios numbered 2,3,4 and 5 plotted against it. Below the results of different scenarios are described separately.

> *Scenario 2 — Low inventory tolerance:* What happens if the planners decide that the accumulation of inventories is wasteful and react to it by lowering the amount of inventory they will accept before reducing investment and prices? In the base case prices and target capacities were adjusted downward when inventories exceeded the expected annual sales. In Scenario 2, price and target capacities are adjusted when inventory exceeds six months worth of expected sales.

Trying to avoid inventory accumulations in this fashion results in production targets growing too slowly to keep up with market demand; inventory backlogs become very large and price adjustments become a regular cyclic process. Prices both rise higher and drop lower than they do in the standard run (or any other of the scenarios considered).

> *Scenario 3 -- Tighter controls in two directions:* Scenario 2 introduced a lopsided tightening of controls; it lowered the tolerance points for inventory accumulation and hastened downward price and capacity target adjustments without altering the tolerance points at which inventory backlogs stimulate upward adjustment of prices and capacity targets. In scenario 3 the inventory tolerances, as in scenario 2, are set at 6 months supply -- half as large as in the base case scenario; meanwhile, tolerances for inventory backlogs (and thus expected waiting times) are also halved from the base case values so that prices are adjusted upwards when expected waiting time reaches 7.5 months and production capacity targets are adjusted upward when expected waiting time reaches 3 months.

Scenario 3 leads to more frequent adjustments and lessened overall deviation from the trend line. Inventory cycles are reduced from about 60 years in the base case and scenario 1 to about 20 years and prices are adjusted upward an downward in the case of each cycle. This seems logical; if you are trying to keep a system within tighter bounds you can expect to have to manipulate its controls more frequently.

> *Scenario 4 -- Loosened controls in both directions:* Given that tightening the upper and lower inventory tolerances for inventory control leads to more frequent adjustment and more tightly bounded system behavior, one would expect that loosening of controls would lead to less frequent adjustment and greater swings in system behavior. In scenario 4 this expectation is tested by taking 'the reciprocal' of scenario 3; instead of halving the base case upper and lower tolerances for inventory fluctuation the two are doubled.

As anticipated, scenario 4 manifests very slow, large swings in inventory behavior. However, because the tolerance that must be exceeded before price adjustment is made is also very large, prices remain unchanged throughout almost the entire 80 years of simulated time.

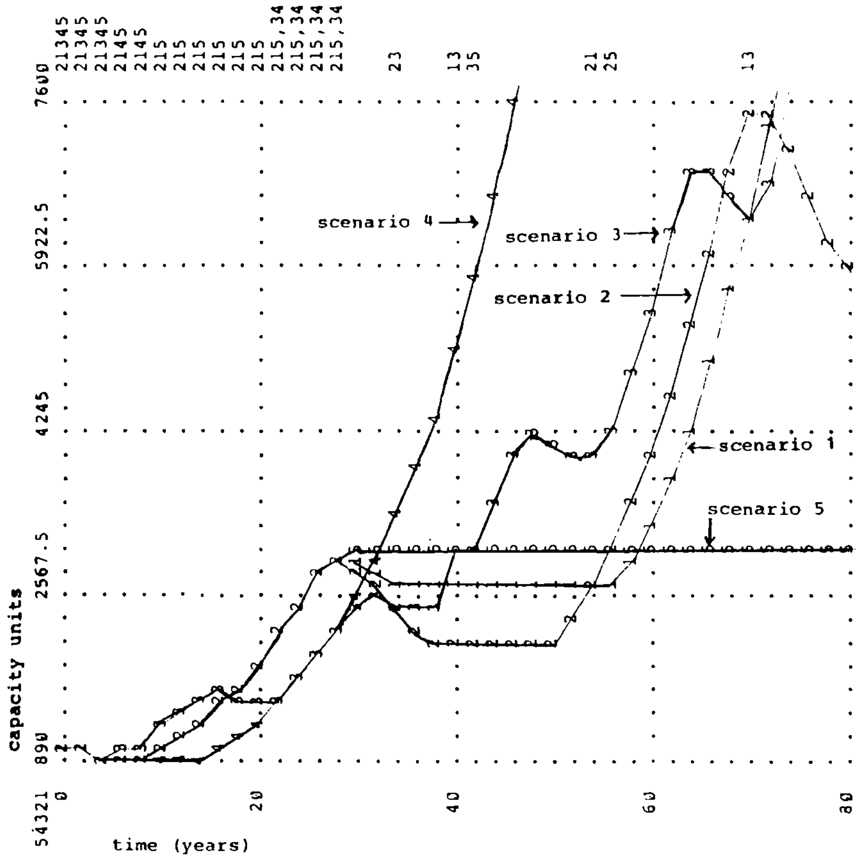

Figure 9a. Production capacities.

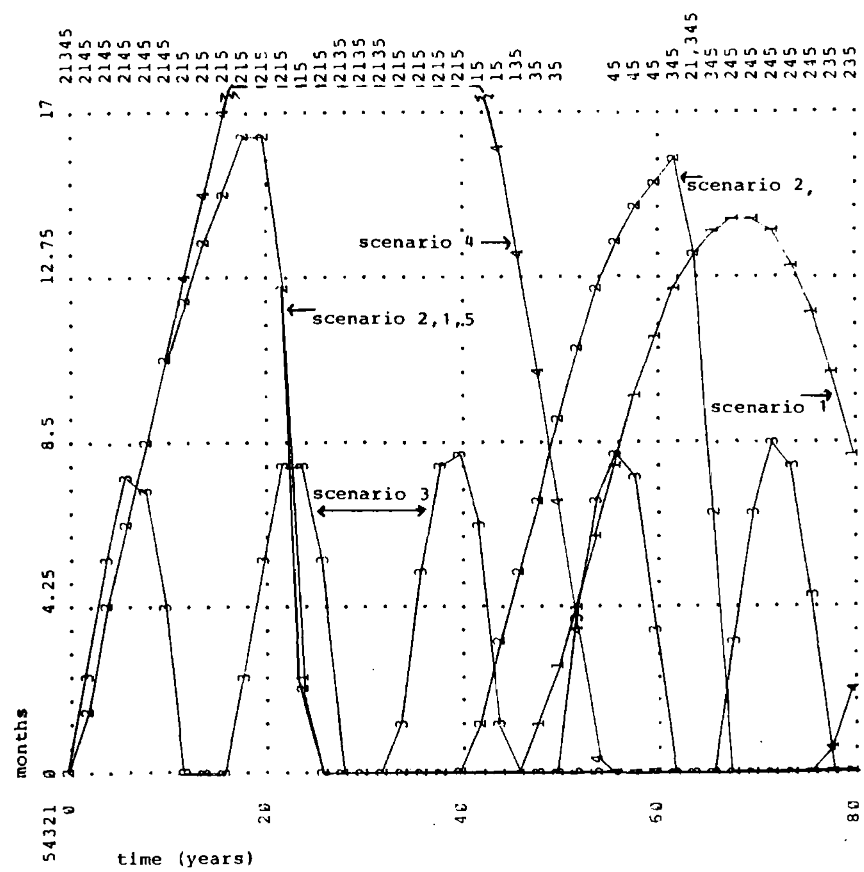

Figure 9b. Expected waiting times.

Figures 9a-d. Comparison of key variables in five different inventory tolerance policy scenarios.

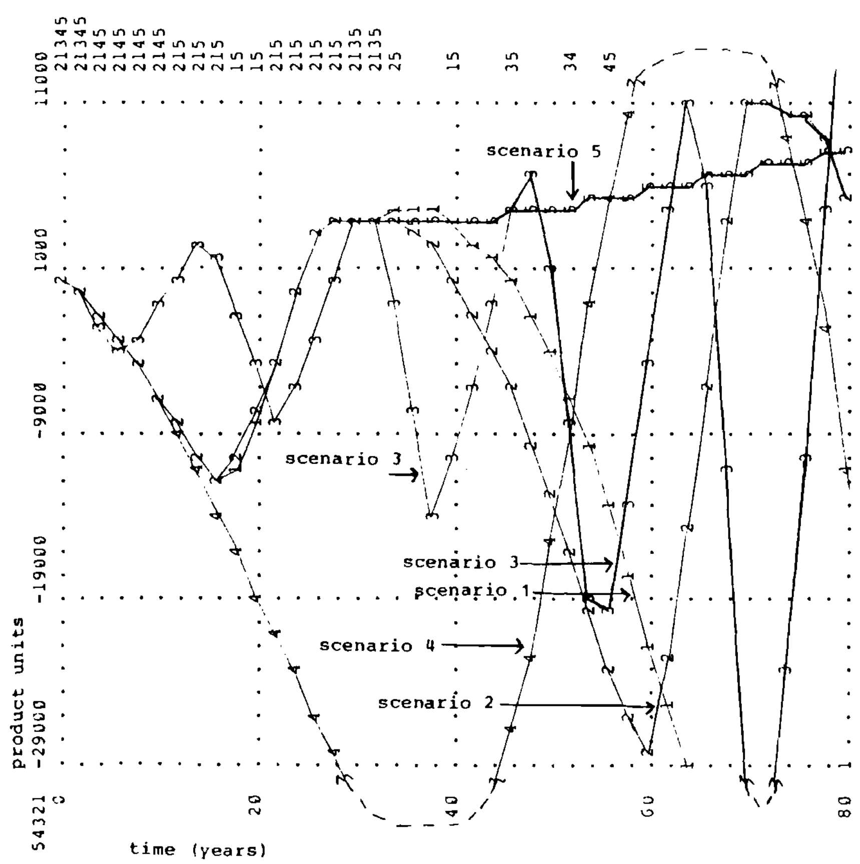

Figure 9c. Product inventories.

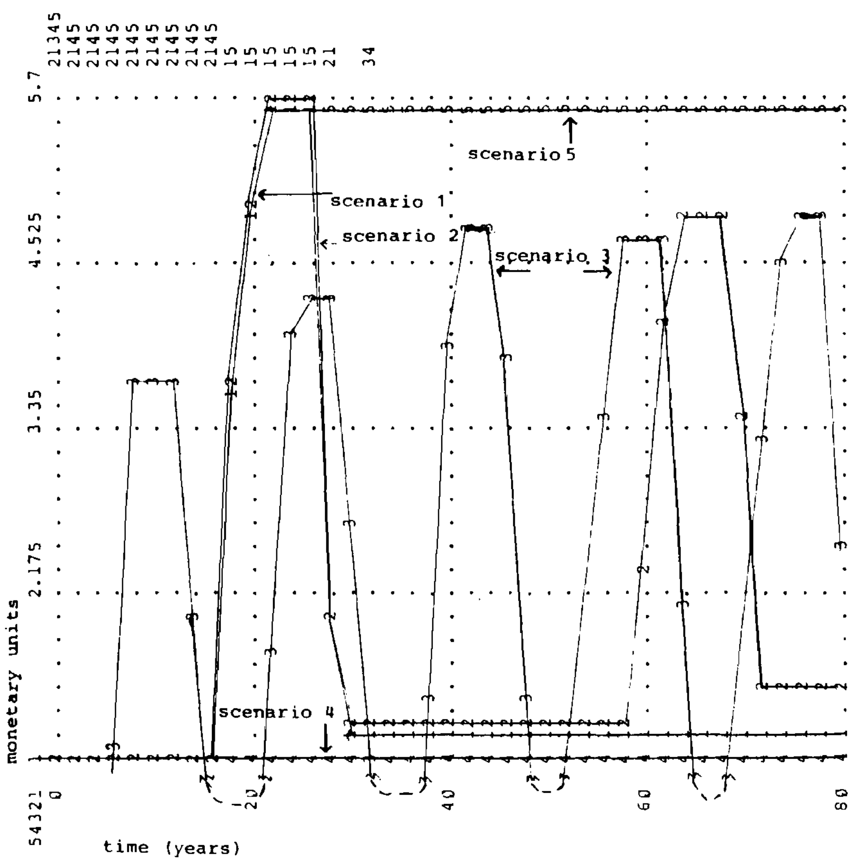

Figure 9d. Prices.

Scenario 5 -- Lopsided expansion of thresholds: Here the inventory thresholds (which affect price and target reduction) are kept doubled, as in scenario 4, while the waiting delay thresholds (which affect price and target increases) are returned to the base case values (half the values of scenario 4). It is noteworthy that the reverse action -- holding inventory thresholds to their base case values while using doubled waiting delay tolerances -- produces output that is virtually indistinguishable from scenario 4. This indicates that the mechanism for downward adjustment of prices and capacity targets was unimportant in scenario 4.

Adjustment Speed Policies:

Figures 10a, 10b, 10c and 10d show the effects of tests altering the speeds at which prices and targets are increased and reduced. The four scenarios considered derrive from alternate halving and doubling adjustment rates as shown below:

scenario	price increase *x$if*	price decrease *x$rf*	target increase *xtif*	target decrease *xtrf*
1 base case	1.5	0.25	0.1	0.1
2 fast	2.0	0.25	0.2	0.1
3 slow1	1.25	0.25	0.05	0.1
4 slow2	1.25	0.125	0.05	0.05

Scenario 2 features price and target increase rates that are twice as fast as those in the base case scenario and decrease rates that are the same as in the base case. (A scenario that doubled price and target reduction rates as well as increase rates was also tested, but it proved identical to scenario 2, thus it is not shown.) Scenario 3 price and target increase rates that are half those in the base case scenario, with decrease rates unchanged. In scenario 4, both increase and decrease rates for targets and prices are halved from the base case values.

In general these tests suggest that faster adjustment leads to larger capacities and inventories. (The higher values may be an artifact of the threshold and adjustment values used in the base case. I have assumed that target decreases are only half as fast as target increases in the base case.) Because capacity and inventory values are generally greater in the fast adjustment scenarios, waiting times and prices remain lower, and price adjustments are less frequent. The model does not show it, but these scenarios also will necessarily require more investment.

Scenario 2, in which target and price rates are twice their values in the base case, has the greatest tendency to increase capacity (see 10a), the largest and fastest inventory swings (10b) and the shortest waiting times (10c) and lowest priced (10d). By contrast, scenarios 3 and 4, which have slow target and price adjustment rates keep lower average values of capacity and inventory and manifest smaller and slower inventory fluxuations than either the base case or fast adjustment cases. in capacity and inventory and maintains the highest prices and the longest waiting times.

It is interesting to note that here asymmetrical adjustment does not appear to be destabilizing; indeed, the model seems insensitive to the speeds at which price and target capacity are decreased. Further testing would be required to establish whether downward adjustments would be more critical in a market that was not growing at 3 percent per year.

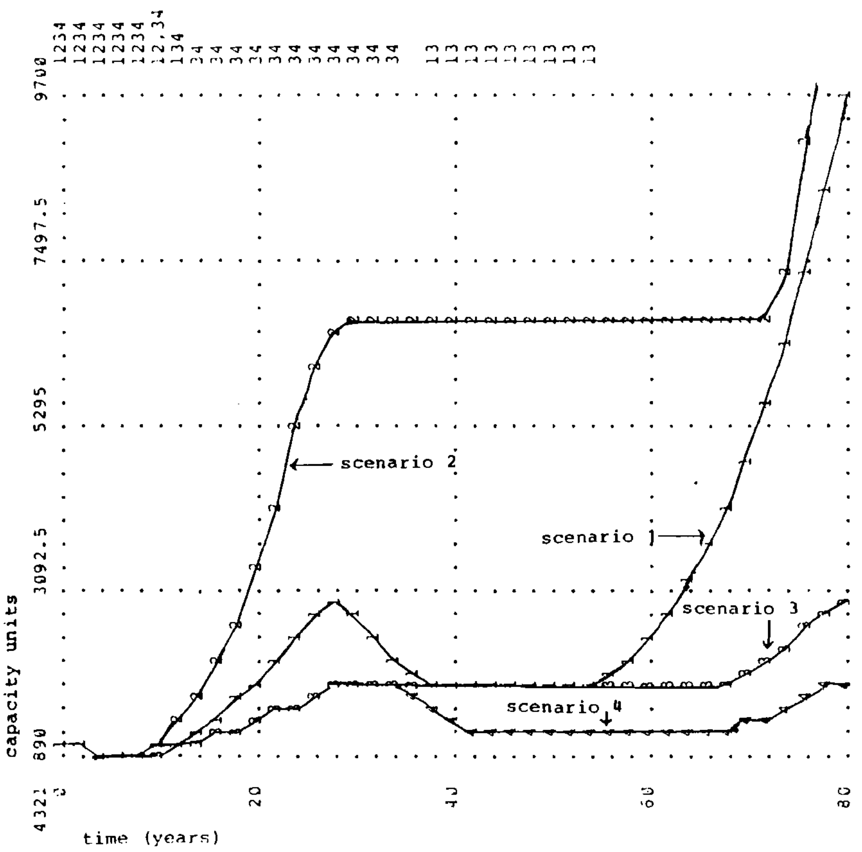

Figure 10a. Production capacities.

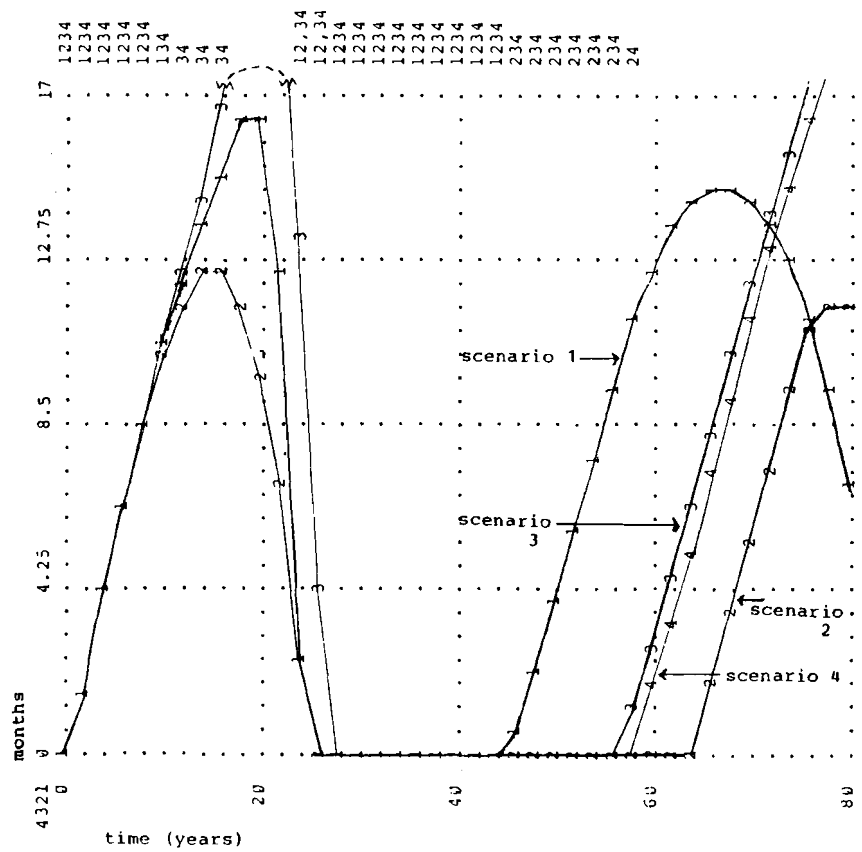

Figure 10b. Expected waiting times.

Figures 10a-d. Comparison of key variables in four different adjustment speed policy scenarios.

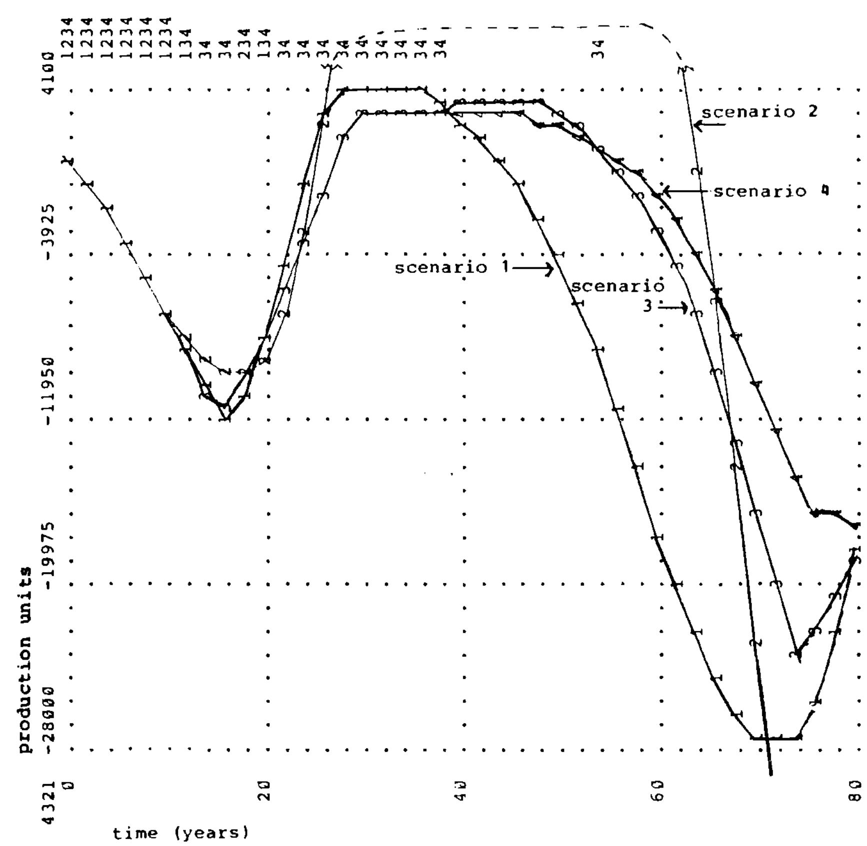

Figure 10c. Product inventories.

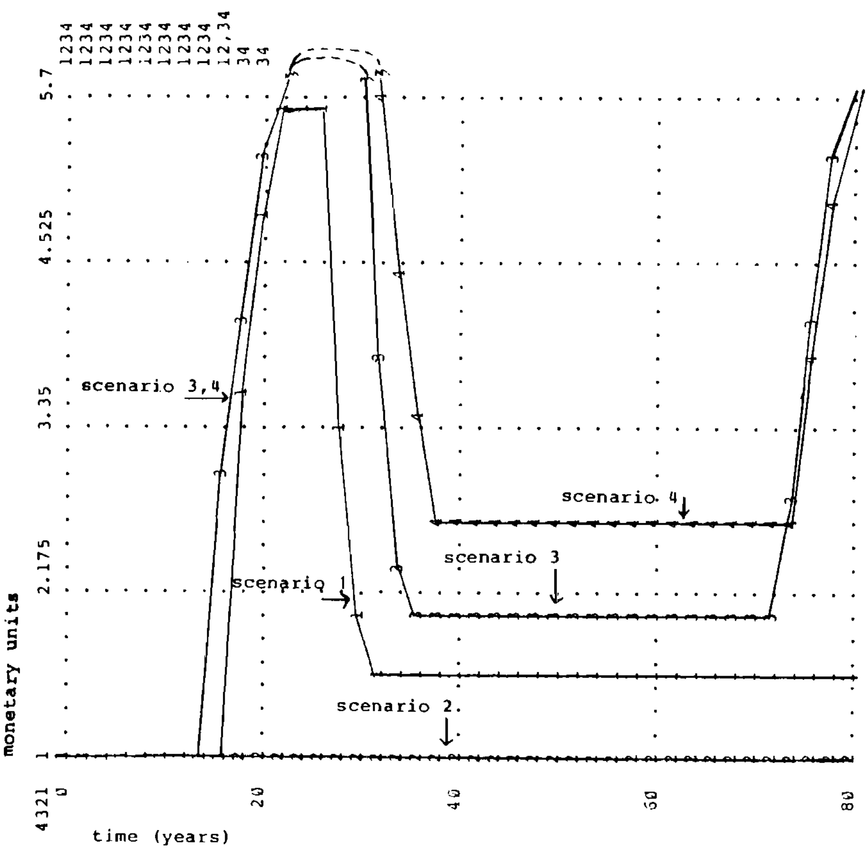

Figure 10d. Prices.

General Remarks on Policy Tests

The tests described above are sufficient only to support some impressionistic remarks about the effects of policy changes within the PLANMKT system. However, they suggest that the system has the following attributes.

First, planners seem to have ability to control many aspects of system behavior, including periodicity and amplitude and mean values of cycles by manipulating variables such as price and conditions at which they change production targets (and investment behavior). Very large differences in system response are caused by varying the threshold values at which prices and investment targets adjusted.

In practice decision-makers are probably more concerned with management of the system as a whole than with regulating the behavior of isolated segments of the production system, and therefore do not often deliberately manipulate specific thresholds to attain desired responses. For example, investment decisions seem to be made through a process of ranking and priority setting between potential areas of investment as much or more than through looking at inventory backlogs or accumulations. Likewise, price setting seems to be oriented to keeping prices in line with input costs and social costs and/or benefits as much or more than it is used for inventory control. Thus while ability to control exists, it is unlikely to be systematically used. This, in effect, means that structures such as PLANMKT are likely to be more useful as forecasting devices than as devices for deciding where to set investment and price levels.

Second, it appears that fine tuning is possible -- if decision-makers are willing to make frequent adjustments and if they keep required balances between control parameters. For example, adjusting the upper bounds in a set of control parameters without complementary adjustment of the lower bounds may destabilize the system. I expect that planners have gained a good intuitive feel for many such features of system behavior; however, there are probably some areas in which intuition leads to suboptimal, if not self-defeating, policies and in which experimentation with formal models could lead to more effective management.

Third, in most cases the system moves slowly. In some cases a full inventory cycle takes 60 years. Given that the USSR is the only planned economy that is over 60 years old, and that no socialist economy has enjoyed disaster-free development (World War 2 counts as a disaster) for more than about 30 years, much of the behavior predicted by PLANMKT can only be speculative. What's more, even if such behavior has been manifested in reality, much of it is unlikely to have been observed because few observational techniques used in economics and/or management will pick up slow sorts of behavior.

Fourth, and most abstractly, because the mechanisms that affect periodic behavior in planned economies appear to have quite different--and perhaps much more variable--time constants than the analagous mechanisms in market economies one might expect to see rather different long term swings in the economic behavior of planned economies. For example, the business cycle and the Kuznets cycle may not exist, but other patterns of systematic modulation may develop.

APPENDIX A: ANNOTATED BIBLIOGRAPHY ON SYSTEM DYNAMICS

Forrester, Jay W. (1973) Industrial Dynamics. Cambridge, Massachusetts: MIT Press.

A relatively old text, first published in 1962, but remains a standard and valuable text. Lays out the precepts of system dynamics and develops some case applications, all of which are industrial. Sophisticated, deserves reading in depth, not recommended for casual reading.

--------- (1968) Principles of Systems. Cambridge, Massachusetts: MIT Press.

Standard elementary text. Solid, but abecidarian. If your background is non-technical and you like to have things simply and clearly explained this is the right text. If you want to get right into the hard stuff, you will find it irritating.

-------- (ed.) (1974) Collected Papers of Jay W. Forrester. Cambridge, Massachusetts: Wright-Allen Press.

For further study. Includes some of Forrester's more important papers. Does better as a complement to basic texts than as a stand-alone volume.

Goodman, Michael R. (1974) Study Notes in System Dynamics. Cambridge, Massachusetts: Wright-Allen Press.

Generally used as an intermediate to advanced text in system dynamics courses. Good as an aid to helping one understand how system dynamics models work. Contains many exercises, not all of which are easy, and answers to exercise questions.

Pugh, Alexander L. III (197) DYNAMO User's Manual. Cambridge, Massachusetts: MIT Press.

The authoritative user's manual for the DYNAMO language (used for most system dynamics simulation). Look for latest edition. Generally not needed as DYNAMO is quite simple to use and other texts supply adequate information.

APPENDIX B: DOCUMENTED PROGRAM LISTING

```
01  title PLANMRK
02  * doc
03  * euler
04  * narrow
05  * nostats

06  l x.k=intgrl(xim.jk-xd.jk)
        x       - real production capacity (units)
        xim     - investment maturation (units/yr)
        xd      - real depreciation (units/yr)
07  n x=xz      - initial production capacity (units)
08  c xz=1000   - initial production capacity (units)
09  r xd.kl=x.k/alc
        xd      - reel depreciation (units/yr)
        x       - real production capacity (units)
        alc     - average lifetime (yrs)
10  c alc=15    - average lifetime (yrs)

  * * * INVESTMENT MATURATION DELAY * * *
11  expnd delay3(xim,xi,xid) investment maturation
12+ l $l11.k=intgrl(xi.jk-$r11.jk)     (units/yr)
13+ n $l11=xi*xid/3
14+ r $r11.kl=$l11.k/(xid/3)
15+ l $l21.k=intgrl($r11.jk-$r21.jk)
16+ n $l21=xi*xid/3
17+ r $r21.kl=$l21.k/(xid/3)
18+ l $l31.k=intgrl($r21.jk-xim.jk)
19+ n $l31=xi*xid/3
20+ r xim.kl=$l31.k/(xid/3)
21- mend
22  n xi=xiz    - initial investment (units)
23  c xiz=67    - initial investment (units)
24  c xid=5     - maturation delay time (yrs)
25  r xi.kl=(xt.k-x.k-xiip.k)*taf
        xim     - investment maturation time (yrs)
        xt      - target capacity (units)
        x       - real production capacity (units)
        xiip    - investment in pipeline (units)
        taf     - target adjustment factor (unitless)
26  c taf=.5    - target adjustment factor (unitless)
27  a xiip.k=($l11.k+$l21.k+$l31.k)-(xid*x.k/alc)
        xiip    - investment in pipeline (units)
        $l11    - investment in first stage (units)
        $l21    - investment in second stage (units)
        $l31    - investment in third stage (units)
        xid     - maturation delay time (yrs)
        x       - real production capacity (units)
        alc     - average lifetime (yrs)
28  l xt.k=intgrl(xti.jk-xtr.jk)
        xt      - target capacity (units)
        xti     - target increase (units/yr)
        xtr     - target reduction (units/yr)
29  n xt=xz     - initial target capacity (units)
        xz      - initial production capacity (units)
30  r xti.kl=clip(xtif,0,xewt.k,xwdt2)*x.k
        xti     - target increase (units/yr)
        xtif    - target increase factor (unitless)
        xewt    - expected waiting time (months)
        xwdt2   - waiting delay threshold (months)
        x       - real production capacity (units)
31  c xtif=0.20 - target increase factor (unitless)
32  c xwdt2=6   - waiting delay threshold (months)
33  r xtr.kl=clip(xtrf,0,xmc.k,xit2)*x.k
        xtr     - target reduction (unitless)
        xtrf    - target reduction factor (unitless)
        xmc     - market coverage (unitless)
        xit2    - inventory threshold (unitless)
        x       - real production capacity (units)
34  c xtrf=.10 - target reduction factor (unitless)
35  c xit2=1    - inventory threshold (unitless)
36  a xmc.k=xpi.k/xes.k
        xmc     - market coverage (unitless)
        xpi     - inventory (units)
        xes     - expected sales (units/yr)
37  a xo.k=x.k*xcu.k
        xo      - output (units/yr)
        x       - real production capacity (units)
        xcu     - capacity utilization (unitless)
38  a xcu.k=tabhl(cuc,xmc.k,0,2,.5)
        xcu     - capacity utilization (unitless)
        cuc     - capacity utilization (unitless)
        xmc     - market coverage (unitless)
39  t cuc=1,.95,.60,.10,0  - capacity utilization
40  l xes.k=intgrl(xsr.jk-xsf.jk)
        xes     - expected sales (units/yr)
        xsr     - sales (units/yr)
        xsf     - sales forgetting (units/yr/yr)
41  r xsf.kl=xes.k/smt
        xsf     - sales forgetting (units/yr/yr)
        xes     - expected sales (units/yr)
        smt     - sales memory time (yrs)
42  n xes=xz    - initial expectations (units/yr)
        xz      - initial production capacity (units)
43  c smt=5     - sales memory time (yrs)
44  r xoa.kl=xo.k
        xoa     - output accumulation (units/yr)
        xo      - output (units/yr)
45  a mkt.k=1000*exp(mgr*time.k)
        mkt     - market size (units/yr)
        mgr     - market growth (fraction/yr)
46  c mgr=0.03 - market growth (fraction/yr)
47  l xpi.k=intgrl(xoa.jk-xsr.jk) inventory (units)
        xpi     - inventory (units)
        xoa     - output accumulation (units/yr)
        xsr     - sales (units/yr)
48  n xpi=xpiz - initial inventory (units)
49  c xpiz=500 - initial inventory (units)
50  r xsr.kl=xpmd.k*mkt.k*mv.k
        xsr     - sales (units/yr)
        xpmd    - price mult demand (unitless)
        mkt     - market size (units/yr)
        mv      - market variation (unitless)
51  a mv.k=normrn(92847,1,msd)
        mv      - market variation (unitless)
        msd     - market standard deviation
52  c msd=.1    - market standard deviation
53  a xpmd.k=tabhl(pmdc,x$.k,0.4,.5)
        xpmd    - price mult demand (unitless)
        pmdc    - price mult demand (unitless)
        x$      - price ($/unit)
54  t pmdc=6,3,1,.60,.4,.3,.24,.2 price mult demand
55  a xewt.k=min(xmc.k,0)*(-12)
        xewt    - expected waiting time (months)
        xmc     - market coverage (unitless)
56  l x$.k=intgrl(x$i.jk-x$r.jk) price ($/unit)
        x$      - price ($/unit)
        x$i     - price adjustment ($)
        x$r     - price reduction ($)
57  n x$=x$z    - initial price ($)
58  c x$z=1     - initial price ($)
59  r x$i.kl=clip(x$if,0,xewt.k,xwdt1)*x$.k*x$lf.k
        x$i     - price adjustment (unitless)
        x$if    - price adjustment increment (unitless)
        xewt    - expected waiting time (months)
        xwdt1   - waiting delay threshold (months)
        x$      - price ($/unit)
        x$lf    - price leverage factor (unitless)
60  c x$if=2.0 - price adjustment increment (unitless)
61  c xwdt1=15 - waiting delay threshold (months)
62  a x$lf.k=tabhl(x$lc,x$.k,0,4,.5)
        x$lf    - price leverage factor (unitless)
        x$lc    - price leverage factor (unitless)
        x$      - price ($/unit)
63  t x$lc=1,1,1,1,.8,.5,.3,.1,.1  - price leverage factor
64  r x$r.kl=x$.k*clip(x$rf,0,xmc.k,xit1)
        x$r     - price reduction ($)
        x$      - price ($/unit)
        x$rf    - price reduction factor (unitless)
        xmc     - market coverage (unitless)
        xit1    - inventory threshold (unitless)
65  c xit1=1.0 - inventory threshold (unitless)
66  c x$rf=.75 - price reduction factor (unitless)

67  parm dt=.1
68  parm start=0
69  parm stop=0
70  parm pltper=2
71  parm prtper=2
```