THE DYNAMICS OF COMMODITY PRODUCTION CYCLES: A DYNAMIC COBWEB THEOREM

by

DENNIS LYNN MEADOWS

B.A., Carleton College
(1964)

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF DOCTOR OF

PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF

TECHNOLOGY

June, 1969

Signature of Author ..
Alfred P. Sloan School of Management, May 15, 1969

Certified by ....
Thesis Supervisor

Accepted by ....
Chairman, Departmental Committee on Graduate Studies

THE DYNAMICS OF COMMODITY PRODUCTION CYCLES: A DYNAMIC COBWEB THEOREM

by

Dennis Lynn Meadows

Submitted to the Alfred P. Sloan School of Management on May 16, 1969
in partial fulfillment of the requirements for the Degree of Doctor of
Philosophy in Management.

ABSTRACT

Commodity exports provide ninety percent of all foreign exchange earnings in the underdeveloped countries. Thus there is much concern about the pronounced fluctuations which characterize the price, production and income of these products. Fluctuations are a function both of the commodity system's inherent stability and of the disturbances (war, drought, business cycles, etc.) imposed upon it. Attempts to decrease the magnitude of fluctuations by altering the production, consumption, or pricing decisions have generally failed for lack of any general theory relating these three to the stability of a commodity system.

In this thesis I review the literature on the only general theory of commodity cycles, the Static Cobweb Theorem. Ezekiel's formulation and the extensions proposed by Åkerman and Nerlove are presented in detail. These static theorems have been little used because they are based upon the static and non-operational concepts of "supply" and "demand".

An alternative approach, the Dynamic Cobweb Theorem, quantifies the individual relationships involved in the production, consumption and pricing of commodities. It includes the relation of inventory to price and the effects of individual biological, physical, and psychological delays inherent in commodity systems. Simulation analyses of the Dynamic Model reveal that it has price-production cycles with phase relationships similar to those in the long-term cycles of all real commodities.

An extensive review of the empirical literature on the U.S. hog system supports the structure of the Dynamic Model and provides for each of its parameters a value characteristic of the hog system. The resulting model exhibits the same four year production cycle as the real system. Less extensive changes in the Dynamic Model to incorporate the biological constants of the relevant system leads to models which exhibit respectively the fifteen year cattle cycle and the 31 month chicken cycle. It is suggested that the Dynamic Theorem also explains the long-term cycles in mineral and vegetable commodities.

Those designing commodity control schemes must consider many alternative policies. To determine the impact of these alternatives on the stability of commodity systems, several are investigated through simulations of the Dynamic Model. Those factors which increase the price-response of production do destabilize the system; factors which increase the price-response of demand tend to increase system stability. Variable utilization of installed production capacity is less effective in decreasing fluctuations than is action to increase or decrease the use of commodity just becoming available for distribution. Processor and distributor pricing decisions are found to have a marked impact on system stability. It is suggested that these pricing decisions may respond to any formal stabilization scheme so as to neutralize its impact on the fluctuations in the commodity system.

Thesis Supervisor: Jay W. Forrester

Title: Professor of Management

TABLE OF CONTENTS

CHAPTER PAGE

I: INTRODUCTION

II: COMMODITY PROBLEMS; MAGNITUDE AND PROPOSED SOLUTIONS

III: THE STATIC COBWEB THEOREM AND ITS EXTENSIONS

IV: THE DYNAMIC COBWEB THEOREM

Dynamic Cobweb Model - Verbal and Quantitative Description

TABLE OF CONTENTS cont.

CHAPTER PAGE

V: TEST OF THE DYNAMIC COBWEB THEOREM - THE U.S. HOG SYSTEM

VI: SOME DETERMINANTS OF STABILITY IN THE DYNAMIC COBWEB MODEL

VII: CONCLUSION

LIST OF FIGURES

LIST OF FIGURES cont.

LIST OF FIGURES cont.

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

It has been a tremendous privilege to work with Professor Jay Forrester. His profound insights into the principles of complex systems and the sharp focus of his own research programs have provided objectives for this thesis and a foundation for the remainder of my career.

Professor Donald Marquis has been a general counselor and teacher throughout my study at M.I.T. His integrity and high standards in the conduct and reporting of research have become benchmarks for my own work.

Without Associate Dean John Wynne's support for a special studies program, the initial phase of this project would never have been undertaken.

Many of the ideas here were refined through discussions with my loyal critic and good friend Dr. Milton Lavin.

The manuscript was improved by Dr. William Martin's comments on the first draft. Professor Carroll Wilson provided the guidance and the contacts needed to direct this investigation to current commodity research.

The facilities of the M.I.T. Computation Center and the comprehensive software packages of Jack Pugh and Donald Belfer saved many months of analytical effort.

To the Sloan School administration I express my sincere appreciation for much administrative and financial support during the past five years. Research, teaching, and study are greatly facilitated by a group of administrators genuinely dedicated to academic excellence.

My wife Donella has been a participant in all aspects of my graduate program. As a scientist, editor, and companion she has encouraged and supported my work and made it all immensely enjoyable.

CHAPTER I

INTRODUCTION

The Problem

In terms of their influence on the long term prospects for international stability, few objectives are more important than that of raising the living standards in underdeveloped countries. Because most of the poorer nations are dependent upon the export of primary commodities for the bulk of their foreign exchange (Table I.1), the pronounced fluctuations which characterize most commodity production have aroused much concern.

Table I.1: Exports from Less-Developed Countries to the Rest of the World.

	Billions of Dollars	Percentage of total
Agricultural commodities (food and raw materials)	10.9	54
Non-agricultural raw materials	2.3	11
Petroleum	5.0	25
All Primary commodities	18.2	90
Manufactures	2.1	10
All exports from less-developed countries to the rest of the world	20.3	100

Source: (U.N.; 1965, p.151)

Inflation, disruption of development programs, loss of investor confidence, and political unrest are only a few of the results commonly attributed to fluctuations in the price and quantity of the commodities exported by the underdeveloped countries. Even the developed countries may find their economies affected. A minor decrease in economic activity of the advanced countries leads to reduced commodity demand. Underdeveloped countries are then able to purchase fewer manufactured goods, further accentuating the initial recession in the advanced countries.

There have been numerous unsuccessful national and multi-national attempts to control commodity prices over the past thirty years, and many articles on the sources, characteristics, and implications of fluctuations in commodity production and price. Yet we are still unable to control commodity systems satisfactorily. Political factors have contributed to the failure. East and West, producers and consumers all have intense and conflicting interests in commodity trade. A more fundamental cause of failure to stabilize prices, however, is our inability to comprehend all aspects of the dynamic interaction between supply and demand for commodities. Though some systematic basis is implied by the presence of a dominant, relatively constant, long term cycle in many commodities, we do not understand its causes well enough to design viable control mechanisms. Wherever stabilization has been attempted, supply or demand has risen inexorably to defeat the control scheme.

There is a strong feeling evident in the literature that each commodity is a law unto itself, that generalizations are not warranted:

> There is little point in comparing the success of the [International Commodity] agreements, one with the other, since each faces the peculiar problems attendant upon the commodity concerned.
> (Baranyai & Mills; p. 18)

> Every commodity - and its frequently numerous grades and sub-types - faces demand and supply conditions different from those of any other commodity. (Wallich; p.349)

This attitude makes systematic study difficult and prevents the mass of data already available on different commodities from being inter-related.

Objectives and Methodology of the Research

Given the ubiquity and tenacity of cyclical commodity fluctuations, it would appear that, in fact, some quite general phenomena must be responsible. If some unique combination of factors were required to produce regular long term cycles, one of the many control schemes surely would have succeeded in arresting their course. It seems more likely that there is some basic cause in all primary commodity systems which leads to their pronounced instability. It is the objective of this research to derive a general dynamic model of the structure underlying long term commodity production cycles, to validate that model and determine its implications for the design of commodity stabilization policy.

If there is a common basis for commodity cycles, it is not to be found in the many exogenous, random influences on commodity systems. It is more likely inherent in the interrelation of supply and demand forces. Industrial Dynamics is a philosophy of systems behavior and a set of simulation aids which seeks the cause of complex behavior in the feedback loops underlying a system's flows of personnel, capital, information, finances, and material. Using Industrial Dynamics techniques it has been possible to identify and then redesign the structure underlying many other socio-economic problems.[1] In this thesis, I apply Industrial

---

[1] For examples in different areas of application see: (Forrester; 1961)- control of industrial production and inventory; (Forrester; 1969) - arresting urban decay; (Nord) - administering the growth of new products; (Packer) management of corporate growth; (Roberts) - management of research and development projects; (Hamilton) - regional economic development.

Dynamics to the problem of commodity production cycles.[2]

Overview of the Thesis

In Chapter II I briefly describe the magnitude of commodity price fluctuations and the current status of stabilization policy. The only other general theory of commodity cycles, the Static Cobweb Theorem, is described in Chapter III through a detailed summary of the Cobweb Theorem literature. I present in Chapter IV an alternative to the Static Model, the Dynamic Cobweb Model, and present preliminary analyses of its behavior. In Chapter V I test the Dynamic Model by determining its ability to explain the distinct cyclical behavior of a specific commodity, hogs. In Chapter VI I analyze the Dynamic Model to determine the influence of several factors upon its stability. The final chapter summarizes the thesis and suggests several extensions of the Dynamic Theorem for future research.

---

[2] This thesis will assume familiarity with the basic concepts and tools of Industrial Dynamics. These are presented in (Forrester; 1961) and (Pugh; 1963, 1968).

CHAPTER II

COMMODITY PROBLEMS: MAGNITUDE AND PROPOSED SOLUTIONS

Definition of Instability and Fluctuation

Although the economic literature does not observe any distinction between a system's fluctuations and its instability, we will find it useful through the remainder of the thesis to distinguish between the two. Stability is an inherent characteristic of any system which determines its response to exogenous disturbances. We speak of stability in reference to an equilibrium point of the system. Equilibrium exists whenever the system levels are unchanging through time. Many different forces may act to displace a commodity system from its equilibrium: war, weather, pests, business cycles in the consuming countries, etc. A stable equilibrium is one which will be re-attained, though usually through converging oscillations, after such a disturbance. One measure of a system's stability is its damping factor, i.e., one minus the ratio of the relative magnitudes of two successive oscillations. The greater the damping factor, the more stable the system. Damping factors will be explained more completely in Chapter III.

Fluctuations are actual movements in any parameter of the system. The magnitude and duration of the fluctuations depend on the size of exogenous disturbances and the system's damping factor. A common measure of system fluctuations is the average magnitude of year-to-year movements in price, quantity, or income about their longer-term trend.

One can seldom influence the magnitude of the exogenous disturbances in commodity systems. Thus we can decrease the impact of fluctuations only by increasing the stability of commodity systems. In our analysis of the Dynamic Cobweb Model, we will simulate the effects of a standard, constant disturbance to determine the relative stability of alternative commodity systems.

Commodity research has generally focused upon the magnitude of fluctuations with little attention to the stability of specific systems. The former can be obtained directly from time series on the system's parameters; the latter can not. Greater fluctuations imply, all else equal, less inherent stability, i.e., a lower damping factor. It is reasonable to assume, however, that exogenous disturbances will vary in magnitude over time and from one commodity to another. Where empirical data does not control for the magnitude of the disturbances, inferences about the stability of different systems must be made with caution.

With that warning, I present data from two empirical studies on commodity fluctuations and summarize the causes which have been advanced in the literature to explain the instability which those fluctuations imply.

Magnitude of Commodity Fluctuations

A United Nations study using statistically derived linear trends found average year-to-year changes in commodity income to average twelve percent (U.N.; 1958, p. 40). Another study, summarized in Table II.1, revealed average yearly changes in individual commodities ranging from three to twenty- six percent.

Reasons Suggested for Instability

There are several widely accepted reasons for the instability implied by the United Nations and other commodity studies. In open trade, price

Table II.1: Primary Commodities: Fluctuations in Trade, 1950-1961

COMMODITY	EXPORT VOLUME	EXPORT UNIT VALUE	EXPORT PROCEEDS
Natural rubber	5	21	21
Cocoa	10	20	15
Linseed	23	17	18
Tallow	13	17	16
Lard	13	17	20
Sisal	7	16	16
Zinc metal	6	16	16
Wool	11	16	15
Jute	10	15	15
Copra	10	15	12
Abaca	11	14	20
Lead metal	7	14	10
Cotton-seed	26	14	25
Copper metal	8	13	16
Olive oil	21	12	18
Palm kernels	6	11	12
Soya beans	24	11	24
Palm oil	5	11	9
Cotton	10	11	14
Barley	15	10	20
Tin metal	8	10	10
Butter	7	10	12
Coffee	7	9	8
Beef and veal	11	9	11
Mutton and lamb	11	9	12
Pork	17	7	21
Maize	10	9	10
Rice	10	9	10
Ground-nuts	10	8	10
Oranges	9	7	8
Tea	8	7	11
Sugar	7	7	9
Aluminum	11	6	13
Synthetic rubber	20	5	18
Wheat	13	5	13
Bauxite	10	4	13
Bananas	5	3	5
Tobacco	7	3	8
Crude petroleum	10	3	9
Average, 39 items	11	11	14

Source: (U.N.; 1965, p.85)

changes act to equate supply and demand. However, the influence of price in moderating commodity systems is decreased by the delays and the low marginal costs inherent in both production and consumption. Supply and demand functions are both relatively price-inelastic.

Delays from one to five years in length, between the decision to acquire new production capacity and its first contribution to output are found in most commodities. Further, commodity production processes often have high ratios of fixed to marginal costs, and there may be heavy penalties associated with the suspension of production. Mines will become flooded, for example, if they are not continuously maintained. Orchards may become infested; fields will erode. Thus, there are incentives to continue production long after price has gone below a level which returns full costs to the producer. Supply inelasticity is modified somewhat by the existence of producer stocks, but technical problems of storage and the costs of deterioration and space minimize their potential impact.

The demand for commodities is similarly inelastic. For some products, consumption is governed more by custom than price. For many others, such as minerals and vegetable raw materials, demand is derived from the product's use in manufactured goods where the commodity's price often constitutes a very small fraction of the total cost.

Technological inflexibility also dampens consumption's short run response to price changes. Production processes or products designed to utilize a specific commodity often can not be quickly changed in response to a fluctuating price. In moderating the difference between supply and demand, consumer inventories are hampered by the same factors which limit the effectiveness of producer stocks. If anything, speculation may lead inventories to play a destabilizing role. It has been suggested that they may be increased in periods of rising price, and decreased when price falls in the face of abundant supply.

It has been reasoned that this supply and demand inelasticity combine to make any commodity system quite unstable in the face of disturbances from weather, pests, diseases, strikes, transportation interruptions, or business cycles. This argument is plausible, but it has been difficult to assess its validity or the relative importance of the various factors discussed above. The Dynamic Cobweb Theorem will incorporate most of these factors and permit us to relate each of them quantitatively to the observed cycles in price and production.

Attempts to Control Fluctuations

There have been four basic approaches to decreasing the fluctuations in commodity proceeds: long-term bilateral agreements, production quotas, buffer stocks and buffer funds. Individual examples of any given approach may differ in their details (sources of financing, for example) but all members of a class share underlying similarities.[1]

Bilateral agreements pledge a consuming and a producing party to the exchange of a specified quantity of commodity within a narrowly defined price range over some (often extended) period of time. Quotas are an attempt, generally by a union of producing countries, to limit and allocate the production for international markets. Buffer stocks attempt to maintain price within specified limits through purchase or sales of the commodity by a stockpiling agency. Supplies are purchased on the open market when necessary to maintain prices above the lower price limit. When demand

---

[1] For a list of commodity agreements see (U.N.; 1965, pp. 88-89)

threatens to force prices above the upper limit, supplies are released from the buffer stock. Buffer funds involve no physical stocks. They smooth producer prices through the use of taxes, variable exchange rates or fixed producer prices. In times of high prices the buffer fund accrues foreign exchange reserves for use in subsidizing producers through periods of low prices. No direct attempt is made to interfere with the international price.

Only four international control schemes are currently in effect: for tin, sugar, wheat, and coffee.[2] When evaluated in terms of their twin goals, price stability and the equation of supply with demand, all have at least partially failed.

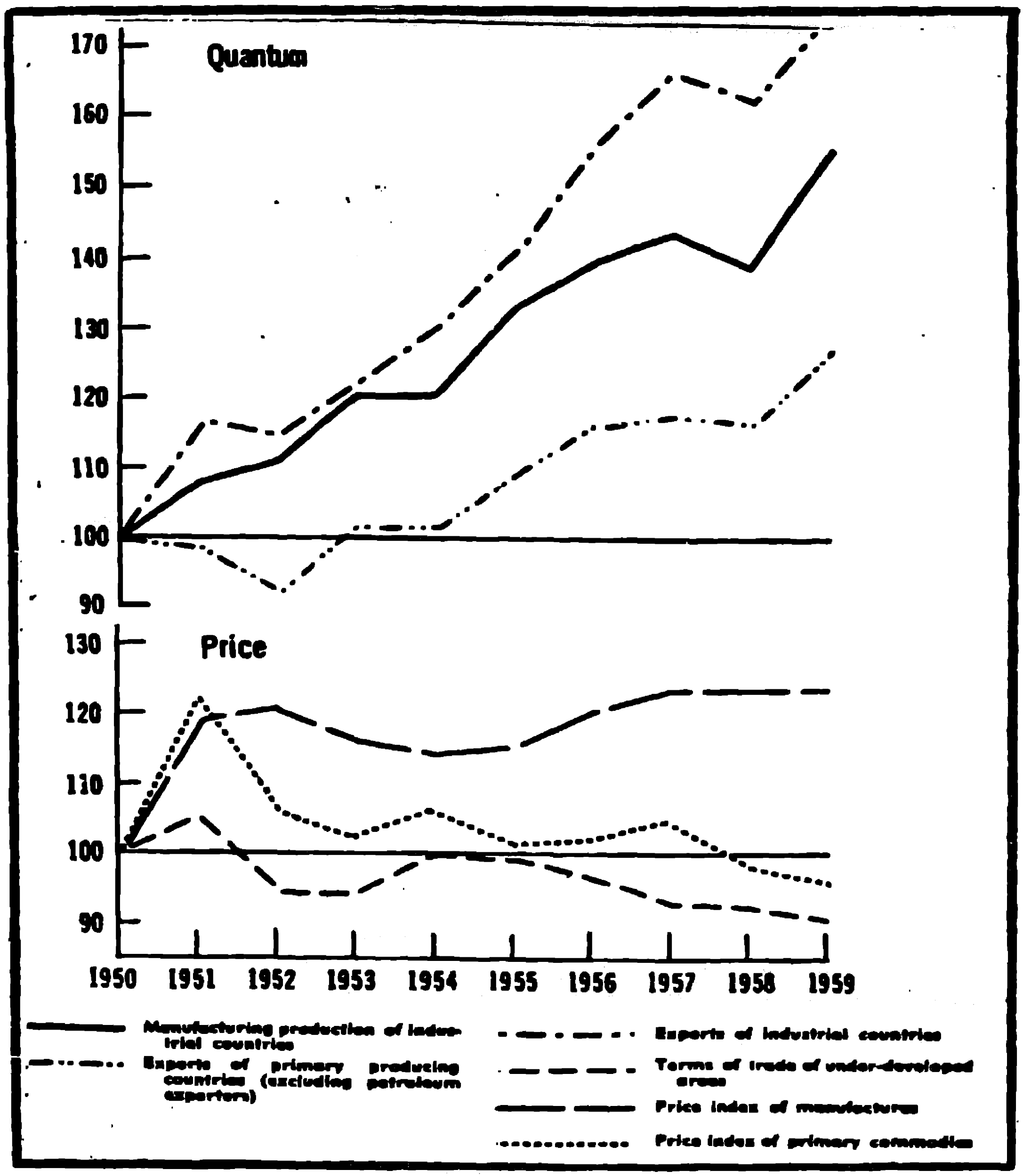
Relative Decline in Commodity Income

The effects of price fluctuations would be less serious if the relative trade position of the underdeveloped countries were not steadily deteriorating. Export incomes of the developed countries rose 26 percent from 1956 to 1961. Commodity income, which accounted for about 90 percent of less developed countries' export proceeds rose only ten percent in the same period. The increase was only three percent if we exclude petroleum and other fuels from these calculations. (Figure II.1)

Foreign aid and private investment supplement export income, of course, but commodities still accounted for 66 percent of the total foreign exchange receipts in the poorer countries during 1960. The relative decline of commodity income is exacerbated by inflation in the unit price

---

[2] The current olive oil agreement provides only for a concerted public relations activity; it does not directly control either prices or quantities. For an assessment of each existing commodity agreement see (Baranyai & Mills).



Source: (U.N.; 1961, p.7)

Figure II.1: Indices of Manufacturing Production in Industrial Countries and of Quantum and Prices of Exports of Industrial and Primary Producing Countries, 1950-1959 (1950 = 100) of manufactured goods.

Many reasons for this income stagnation have been offered. Demands for food stuffs in the advanced countries grow little with income. Advancing technology at the same time increases the efficiency of raw material use and provides synthetic competitors for many of the commodities' traditional markets. No doubt, too, the relative undifferentiation of commodities has made it impossible to sustain the high profit margins characteristic of manufactured goods. These trends seem certain to continue. The final chapter discusses the interrelation of stability and growth in commodity systems and indicates how the Dynamic Theorem may be extended to study their interaction.

Attempts to Avoid Income Stagnation

There has been less attention in the literature to the problem of relative income decline. The typical reaction among producer governments has been some attempt to fix prices artificially above the level which would obtain in the free market. These efforts have been hampered, however, by the reluctance of consuming countries to participate. In the long run, each effort generally collapses as surpluses accumulate and consumers switch to competing products or suppliers, leaving the producer in a less favorable position than at the initiation of his price-fixing program. Though some analysts question the economic severity of these problems, see for example (MacBean), the tensions and the frustration which they engender are very real. The political importance was brought cogently to the attention of our government at the 1964 and 1967 UNCTAD conferences (United Nations Conference on Trade and Development) where the U.S. found itself politically isolated among the developed and underdeveloped countries in its support of traditional arrangements for international commodity trade. At that conference it was concluded:

> One of the chief difficulties in the actual negotiation of international commodity agreements has been that the participating Governments have not always been fully conscious of which .... objectives they were aiming at; nor were they fully conscious of the extent to which any one of these objectives, or a combination of them, could be successfully attained by one or the other of the standard types of agreement-techniques. (U.N.; 1965, p. 141)

Without a theoretical understanding of commodity production cycles, these difficulties will continue to hinder international action. In Chapter III I will review the literature on the only general theory thus far advanced to explain commodity cycles, the Static Cobweb Theorem.

CHAPTER III

THE STATIC COBWEB THEOREM AND ITS EXTENSIONS

Definitions

It is necessary to define several of the terms which we will employ in presenting the Static and the Dynamic Cobweb Theorems. Economic analysis is essentially the attempt to relate postulates about the process of resource allocation to the dynamic behavior of producing and consuming systems. Theorems are the fundamental building blocks of economic analysis. Every theorem has three components: definitions, assumptions, and conclusions.[1] A specific set of definitions and assumptions about the relationships among elements in a system constitutes a model of that system. Conclusions are derived from a model through various means of analysis: verbal reasoning, geometrical representation, mathematical analysis, simulation. The conclusions resulting from a set of assumptions must be independent of the mode of analysis, but every analytical tool will place some constraints upon the number and type of assumptions which may be accomodated by the theorem for which it is used.

One set of assumptions underlies all Static Cobweb analyses, whether they are conducted verbally, geometrically, or mathematically. Those assumptions and the resulting conclusions about system stability will be referred to as the Static Cobweb Theorem. Analysis through computer simulation makes it possible to eliminate several restrictions. The more realistic set of postulates and the conclusions about system behavior which are derived from them by simulation analyses will be called the Dynamic Cobweb Theorem.

---

[1] This terminology is adapted in part from that presented in (Cohen & Cyert).

Static Cobweb Model

A general formulation of the Cobweb hypotheses includes three assumptions about production and consumption within a commodity system:

1. Consumption is a decreasing function of the price recognized by consumers.
2. Production is an increasing function of the price which was expected by producers when production was initiated.
3. There is a lag between initiation of production and availability of the resulting commodity.

These assumptions form the foundation of both the Static and the Dynamic Cobweb Models.

Limitations inherent in the analytical tools available to economists have traditionally forced several additions to these basic assumptions to make the model more tractable analytically:

4. Producers act as if their decisions will not influence future prices.
5. Producers will always expect the existing market price to continue indefinitely into the future.
6. Production, consumption, and inventory decisions can be summarized by supply and demand curves, which are both functions only of price.
7. The continuous evolution of a system may usefully be divided into segments each equal in length to the lag between initiation of production and ultimate availability of the commodity.
8. Price adjusts in each period so that supply and demand are equated for the period.

9. One irrevocable production decision is made in each period on the basis of current expected price.
10. Production initiated in one period is only and wholly available in the next.

Together, the ten statements constitute the Static Cobweb Model. The restrictions permit one to approximate a real system's continuous sequence of prices with a series of equilibrium prices calculated for each of several consecutive periods.[2] For such a system only the supply and demand curves and the commodity's price in period "t-1" are required to predict its equilibrium price in period "t". Price in "t" determines production in "t+1", so that the behavior of the commodity system is fully determined.

Static Cobweb Conclusions

The implications of these ten assumptions were initially derived geometrically. A recent article employed mathematical analysis.[3] Either approach concludes that there are three possible behavior modes for price and production: divergent, sustained, or convergent oscillations, with the two parameters 180° out of phase.

---

[2] This approach to dynamic system behavior, known as "period analysis" is discussed by Samuelson, who presents the Static Cobweb and several other theorems as examples.

[3] The theorem was first developed with geometric analysis of the supply-demand relationships by three authors independently: Ricci, Schultz, and Tinbergen, all in 1930. Ezekiel summarized and extended the earlier work, again geometrically, in 1938. His paper is the classic exposition of the Static Cobweb Theorem and is the basis for all subsequent work. Nerlove rederived the Static Cobweb conclusions mathematically in 1961.

Any oscillation may be characterized by two parameters, its period, and its damping factor. The period of an oscillation is the time which elapses between two consecutive peaks. The Static Cobweb Theorem concludes that the period of commodity oscillation should be just twice the length of the production delay. The damping factor equals one minus the ratio of the relative magnitudes of two successive peaks. When the damping factor is negative, the system exhibits divergent, i.e., explosive, oscillations. Where the damping factor equals zero, fluctuations continue indefinately. When the factor is between zero and one, oscillations are steadily diminished, and equilibrium will ultimately be reached in the absence of any subsequent disturbances. The principal conclusion of the Static Theorem is that a commodity system's damping will depend upon the price elasticities of its supply and demand schedules (Table III.1)

Table III.1: Relation of Supply and Demand Price Elasticities to the Behavior of the Static Cobweb Model.

ELASTICITIES	BEHAVIOR
Supply < Demand	Convergent Oscillations
Supply = Demand	Sustained Oscillations
Supply > Demand	Divergent Oscillations

Employing the agricultural terminology most often used in presentations of a Cobweb Theorem we may illustrate the static analysis of a hypothetical commodity both geometrically and mathematically.

Geometrical Analysis

Assume a demand and a supply curve, Q_d and Q_s (Figure III.1a) with

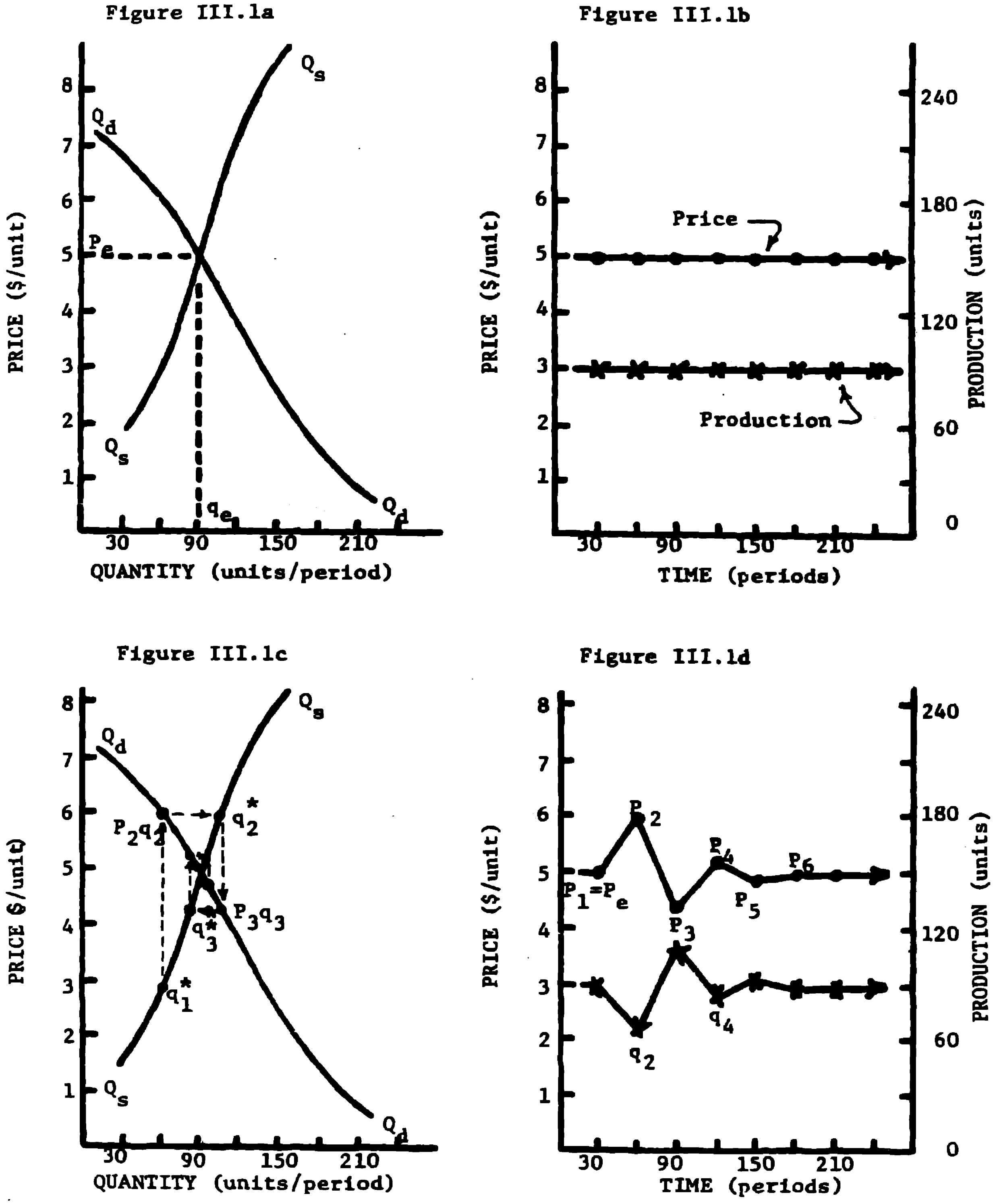


Figure III.1a

Figure III.1b

Figure III.1c

Figure III.1d

Figure III.1 Geometrical Analyses of the Static Cobweb Theorem elasticities as specified by the Static Cobweb assumptions above. At equilibrium, in this example, ninety units of product will be initiated in each period, ninety units will be consumed, and the price will remain at \$5.00 per unit. The assumptions give no definite information on the behavior of price and production between successive equilibrium points, but we will make the usual, though unwarranted, assumption that it changes linearly. In that case, the time series for equilibrium price and production in successive periods would be that shown in Figure III.1b, $P_t = P_e =$ \$5.00 per unit; $q_t = q_e = 90$ units; $t = 1,2,3,\ldots$

Any of several factors might disturb this commodity system from its equilibrium. Disease or weather could suddenly decrease the amount available in one period. A sudden shift in either the supply or the demand schedule might mean that production and consumption are no longer equated at the former equilibrium price, \$5.00 per unit. Assume, for example, that the weather has destroyed one third of the crop in period 1, and that only sixty units of the commodity will be available in period 2 (Figure III.1c). That decreased amount will be purchased at a price $P_2 > P_e$. This higher price leads the producers to initiate an amount q_2^*. By assumption #8, consumption will just equal production in period 3. However, q_3 will only be cleared from the market at a price P_3, which is lower than both the previous price, P_2, and the equilibrium price, P_e. One could continue to trace the reactions alternately between supply and demand schedules to obtain the time forms predicted for this commodity by geometrical analysis based on the Static Cobweb assumptions. The resulting time series for prices and production are represented in Figure III.1d. In this instance, supply is less elastic than demand so that the oscillation is convergent, the damping factor is positive, and equilibrium is reattained. The period of the fluctuation is two time periods or twice the production delay, used here as the unit of time.

If the price-elasticity of supply and demand for this commodity had been assumed equal, it could similarly be shown geometrically that the initial disturbance leads to sustained oscillations. Divergent oscillations would result if the product's supply curve were assumed to be more price elastic than its demand curve. These conclusions can also be derived from a mathematical analysis of the assumptions #1 - #10 above.

Mathematical Analysis

In a derivation adapted from (Nerlove), we assume that the supply and demand functions may be represented in the vicinity of their intersection by the linear functions:

$$q_t^D = a + bP_t$$

$$q_t^S = c + dP_{t-1}$$

Since we assume for static analyses that $q_t^D = q_t^S$, within each time period (assumption #8, p. 26):

$$(1)\quad P_t = \frac{c - a}{b} + \frac{d}{b} P_{t-1}$$

Consequently:

$$(2)\quad q_t^S = c + d \left[\frac{c - a}{b} + \frac{d}{b} P_{t-2} \right]$$

When the system is in equilibrium:

$$P_t = P_{t-1} \equiv P_e = \frac{c - a}{b - d}$$

$$q_t^S = q_{t-1}^S \equiv q_e = c + d \left[\frac{c - a}{b - d} \right]$$

Assuming that the initial price, P_o, is something other than P_e. what will be the sequence of prices, P_1, P_2, ...? Equation (1) has the solution:

$$P_t = P_e + \left(\frac{d}{b}\right)^t \left[P_o - P_e\right]$$

The sequence of prodution is thus:

$$q_t^S = c + dP_e + d\left(\frac{d}{b}\right)^{t-1}\left[P_o - P_e\right]$$

By assumption $d > 0$, $b < 0$. Thus, $d/b < 0$ and P_t may only oscillate; it may not exhibit monotonic growth or decay. The type of oscillation will be the same for both price and production, though they will be 180° out of phase, and it will depend upon the relative magnitudes of b and d, the price-elasticities of demand and supply.

Table III.2: Summary of Nerlove's Static Cobweb Model Analysis

$0 > \frac{d}{b} > -1$	P_t and q_t converge to their equilibrium points
$\frac{d}{b} = -1$	P_t and q_t undergo sustained oscillations
$\frac{d}{b} < -1$	P_t and q_t diverge from their equilibrium points

Given the same assumptions, both means of analysis lead to identical predictions for the behavior of price and production.

Revised Static Cobweb Model

Of the many simplifying assumptions in the Static Cobweb model, none have received more criticism in the literature than those specifying the manner in which production responds to a change in price. For the case of a step increase in price, production in the Static Model responds as illustrated in Figure III-2:

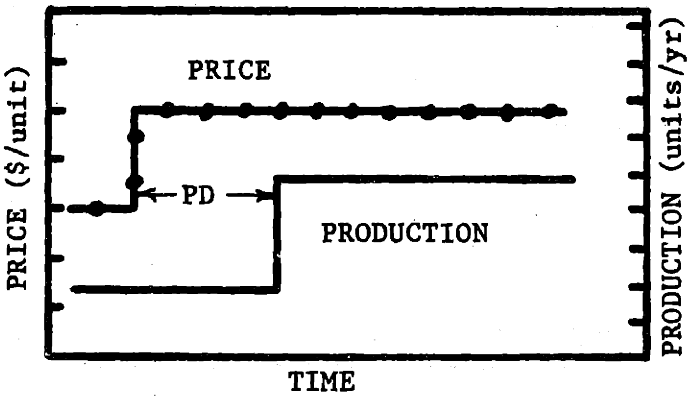


Figure III.2: Static Price-Response of Production

Empirical evidence on the influence of price changes in actual commodity systems contradicts this assumption:

> There appears to be a general type of production response to price, common to each of the (agricultural commodity) cases analyzed. In each case the price received for the production of the preceding season is the dominant factor in production in any given year. In most cases the price received during the season two years preceding is also an important factor, particularly if the price has been low. (Bean; p. 369)

The behavior often exhibited in actual commodity systems, then, is more nearly similar to that in Figure III-3:

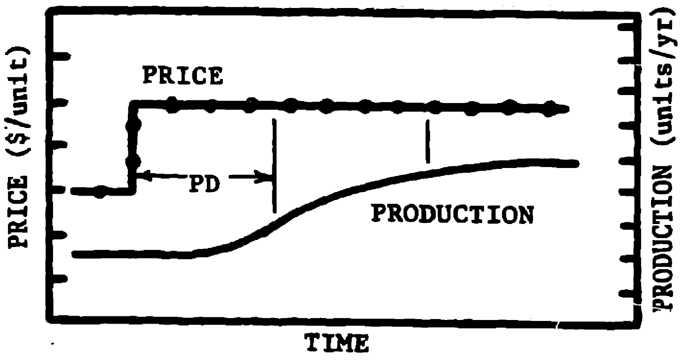


Figure III.3: Dynamic Price-Response of Production

Four processes intervene between a price change and the subsequent adjustment in production (Table III.3):

Table III.3: Processes Intervening Between Price and Production Changes

1. formation of producers' price expectations.
2. determination of the appropriate response.
3. acquisition (disposal) of productive capital and corresponding change in the initiation rate of new commodity.
4. production or maturation of the commodity.

The Static Model assumes the first three to occur instantaneously. The fourth is assumed to require one production (or growth) period. Åkerman and Nerlove have considered models in which these assumptions no longer hold. Their analyses indicate both the importance of changes in these relationships and the difficulty of deriving their implications through the traditional modes of analysis. I will examine their analyses in detail, for Nerlove's addition to the Static Model will be employed to represent distributor and producer expectations in the Dynamic Model.

Akerman's Geometrical Analysis

Akerman recognized that net changes in inventory, producers' delay in acknowledging price changes, and the physical constraints upon the rapid exchange of productive capital among competing uses all influence the response of production to price.

> If a sudden increase in demand or a bad harvest and diminished current supply with rising prices occurs, some part of the regular stocks will be utilized before the time when the next harvest is due. (p. 153)
>
> And when the price P_a has risen, the farmer, generally, will not be convinced it will remain so elevated until several years have elapsed. (p. 154)
>
> If a farmer has experienced an appreciable price change for one of his products A and, therefore, wants to extend its cultivation during the following year, he will meet with greater immediate difficulties than if the extension could be brought about gradually over a period of years. The existing crop rotation system is generally more difficult to change immediately than in the long run. (p. 154)

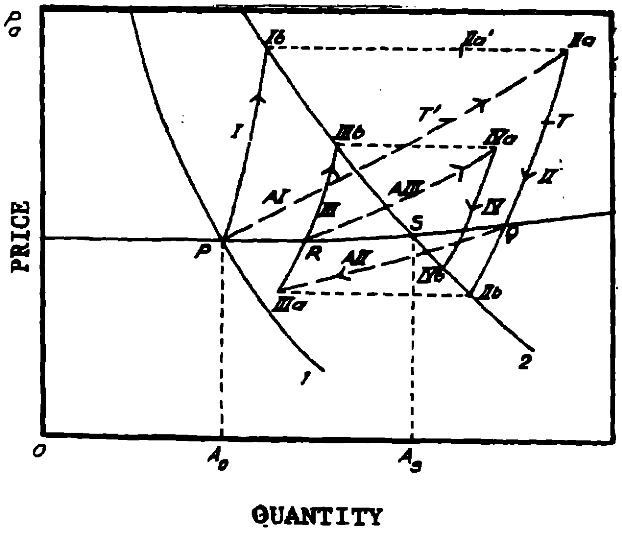
He concludes that the result should be:

> A rise in P_a at the beginning of the cultivation year, therefore, will cause an increase in supply at the end of that year considerably lower than the ultimate increase resulting from a lasting price rise of the same magnitude. (p. 154)

To accomodate the influence of these changes in the model, Åkerman defines three supply curves which differ in their time frame and, consequently, in their price elasticity. We are asked to imagine a commodity system in which:

> Between the sharply rising market supply curve and the very slowly rising long-term normal supply curve there exists, accordingly, for some time following the current cultivation year a moderately rising short-term normal supply curve. (pp. 154-155)

The market supply schedule relates price to the supply which will exist before the next harvest. Supply during this period consists of production plus any change in stocks. The short term normal supply curve expresses the relation of production to price after the current cultivation year but before farmers have adjusted fully to price. The long term normal supply curve indicates the total yearly commodity production which would eventually be forthcoming should the price remain at any given level. The latter curve thus expresses the long run, equilibrium supply-price relationship. A geometric representation of the model is employed to analyze the impact of a sudden shift in demand on the price and production of the commodity. Åkerman concludes that the commodity system would return to equilibrium even when production in the long run is substantially more price elastic than demand (i.e., when $d/p \ll -1$). Analysis of the model is unfortunately quite cumbersome and qualitative (Figure III.4).



The converging fluctuations shown in our treatment depend on our assumption of a series of different, successively arising and vanishing, moderately elastic short term normal supply curves. (p. 158)

Figure III.4: Åkerman's Geometrical Analysis of the Revised Static Cobweb Model

It would be impossible to trace geometrically the implications of a second disturbance in Åkerman's model which occurred before the transient effects of the first had died out. Nevertheless, the presentation does at least suggest that price-production relationships characteristic of actual commodity systems may substantially alter a commodity system's stability from that predicted by the simple Static Cobweb Theorem. This conclusion is supported by the more specific model and analysis of Nerlove.

Nerlove's Mathematical Analysis

One feature of Åkerman's model is the assumption that producers do not adjust their forecasts instantaneously to the most recent market price. Rather, they tend to discount recent changes. Nerlove and Arrow had earlier proposed a similar quantitative model of price forecasting which they designated "adaptive expectation".(Arrow & Nerlove).

(1) $P^*_t = P^*_{t-1} + B(P_{t-1} - P^*_{t-1}),\quad 0 < B \leq 1$

P^*_t -- Price Expected to Obtain in Period "t"

P_t -- Market Price in Period "t"

B -- Coefficient of Expectations

Nerlove has incorporated this assumption in an otherwise Static Cobweb Model to determine its implications for the relationship of relative supply and demand elasticity to stability of the commodity system.

Assume, as before, that the supply and demand functions may be represented by linear functions in the vicinity of equilibrium. Demand is again determined by current market price, but supply in each period is a function of the price producers had earlier forecast for that period.

(2) $q^D_t = a + bP_t$

(3) $q^S_t = c + dP^*_t$

from (1) and (3):

$$q_t^S = c + d\,[\,P^*_{t-1} + B(P_{t-1} - P^*_{t-1})]$$

$$= c + dP^*_{t-1} + dBP_{t-1} - dBP^*_{t-1} + (cB - cB)$$

$$= (1 - B)(c + dP^*_{t-1}) + cB + dBP_{t-1}$$

$$(4) \quad = (1 - B)q^S_{t-1} + cB + dBP_{t-1}$$

By assumption in the Static Cobweb:

$$(5) \quad q_t^S = q_t^D = q_t \ , \quad q^S_{t-1} = q^D_{t-1} = q_{t-1} \ , \ \ldots$$

from (2) and (4):

$$q_t = (1 - B)(a + bP_{t-1}) + cB + dBP_{t-1}$$

$$(6) \quad = [b + B(d - B)]\ P_{t-1} + a + B(c - a)$$

from (2) and (4):

$$a + bP_t = [b + B(d - b)]P_{t-1} + a + B(c - a)$$

and $$(7) \quad P_t - [1 + B(\tfrac{d}{b} - 1)]P_{t-1} = \frac{B(c - a)}{b}$$

We define P_e as the price which equates q_t^S and q_t^D and $P_o \neq P_e$ as the initial price (as, for example, after some initial disturbance from equilibrium). Then (7), a first order difference equation in P_t has the solution:

$$(8) \quad P_t = P_e + (P_e - P_o)[1 + B(\tfrac{d}{b} - 1)]^t$$

For P_t to converge to P_e, as t increases, it is necessary that:

$$(9) \quad |1 + B(d/b - 1)| < 1$$

Relationship (9) is both necessary and sufficient for convergent oscillations. It may also be written:

$$(10) \quad 1 - 2/B < d/b < 1$$

When $B = 1$, (10) reduces to:

(11) $-1 < d/b < 1$ (the requirement for convergence in the simple Static Model)

Where $0 < B < 1$, system fluctuations will converge over a wider range of supply and demand elasticities than in the classic case. This, in more precise terms, is the conclusion derived by Åkerman.

Implications of the Static Cobweb Extensions

These extensions of the classic Cobweb Theorem have profound implications for its validity and utility. They indicate that even very simple, albeit more realistic, assumptions about the price-production relationship may change our predictions about the stability of a commodity system. While Nerlove analyzed only the influence of a change in the process of price forecasting, it should be clear that the formation of expectations is little different from the investment decision, or the acquisition of production capacity or the maturation (production) of the capacity in its effect upon the dynamic relationship between price and production. All of these invalidate the strict one-period lagged response assumed in the Static Model and thereby alter the system's stability from that predicted by the Static Theorem.

It is important for those designing control policies to understand the implications of alternative assumptions about each of these four processes, for commodity stabilization policy may act upon any one of them. It is theoretically possible to institute producer information systems; to provide restrictions or assistance in changing the level of productive capacity; or to use new breeds, varieties, procedures, or more intensive cultivation to shorten biological and physical delays.

Because one small change in the Static Model, adaptive producer expectations, caused important changes in the conclusions about system stability, it is important to develop a more realistic model which explicitly represents all the processes relating price, production, and consumption. Verbal and geometrical analyses were extended past their capabilities by Åkerman. They will clearly be inadequate for a more complex model. Because the necessary changes in the Static Model are numerous and include non-linearities, mathematical analysis will also be impossible. After incorporating the factors in Table III.3 and assumptions about price and consumption into the Dynamic Cobweb Model, we will thus employ simulation analysis to study the determinants of commodity system stability.

CHAPTER IV

THE DYNAMIC COBWEB THEOREM

Overview of the Model

The detailed discussion of the relationships in the general model should not be permitted to obscure the basically simple structure underlying commodity production cycles. The essentials of that structure are two coupled negative feedback loops, consumption and production, each acting to adjust inventory coverage to the desired level.

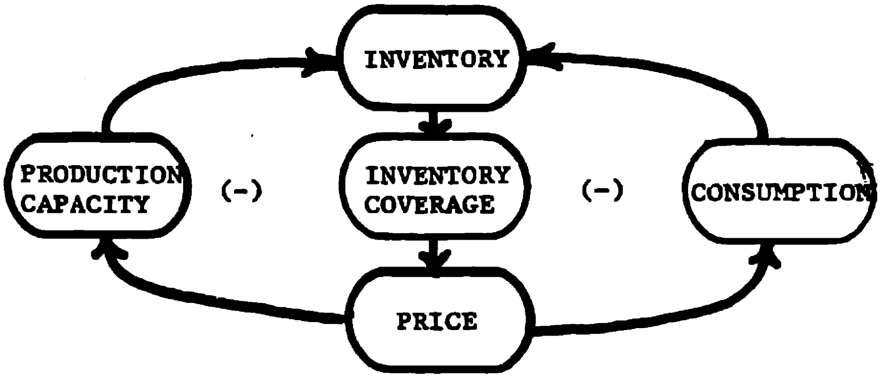


Figure IV.1: Feedback Loop Structure of Production Cycles

In commodity systems the goal implicit in both the production and the consumption relationships is the maintenance of inventory at a particular level. When stocks are lower than desired, for example, price increases. This increase effects changes in both the production and the consumption sectors which act to return inventory to its desired level. The price increase lowers per capita consumption of the material. With less drain on inventories, they will tend to rise. Production relationships act with the same effect. The increase in current price raises producers' price forecasts and thus the capacity they wish to utilize. After acquisition delays, additions to capacity result in increased production and higher inventory.

Were inventory to rise above its desired level, the resulting price decrease would again be propagated around both the production and the consumption loops to yield counteracting forces, decreased production and increased consumption.

It will be easier to focus on the essentials of this underlying feedback structure if we do not simultaneously concern ourselves with estimating the parameters of a specific commodity. Thus we turn now to presenting the general Dynamic Cobweb Model, the relationships which are hypothesized to cause all long term commodity production cycles. In Chapter V we will set the parameters of this general model to values which characterize a specific commodity system.

Dynamic Cobweb Model - Introduction

In moving from verbal, geometric, or mathematical analyses to simulation studies, all practical constraints on the complexity of an economic model are removed. Models of individual commodities may be dynamic, nonlinear, and as detailed as desired. However, it is postulated that a complicated model is not required to explain long-term commodity instability. The three fundamental Cobweb assumptions (p.26) should, in fact, include the essential elements of the structure underlying long term cycles. The Dynamic Theorem is based upon those assumptions. The restrictions inherent in assumptions #4 to #10 of the Static Model, which were imposed primarily to facilitate analysis, are eliminated. In the Dynamic Model:

- producers may employ any function of current and past prices to form their expectations about future prices.
- emphasis is upon actual commodity, capital and information flows. The model includes an inventory of processed commodity which serves to decouple production and consumption over the short run.
- we shift from the "period" to the "rate" form of analysis. Production and consumption are assumed to adjust continuously to price changes, not abruptly from the equilibrium point in one period to that in the next.
- price is determined by those who hold inventories through interaction with producers and consumers. As inventories rise above the desired level those holding stocks will decrease price to discourage production and raise consumption. When inventories fall below the level desired by those holding them, prices will be increased.
- delays important in the behavior of real commodity systems are explicitly included in the model:

1 - producing commodity
2 - forecasting producers' price
3 - forecasting consumption
4 - recognizing retail price
5 - responding to price forecasts
6 - transferring productive capacity

Until we are able to test a model based upon the above assumptions, we will accept them as working hypotheses for use in defining the individual relationships of the general model. Although these relationships will be presented initially without verification, they are empirically based. Discussions with commodity economists and an extensive study of empirical literature on different aspects of specific commodities have provided the author with the generalizations incorporated in the Dynamic Model. However, with three exceptions to be noted, the relationships are so diffused through the literature that it is not particularly useful to give citations. When we turn to the examination of a specific commodity in the next chapter, it will become appropriate to cite specific studies in support of each assumption. The elements of the Dynamic Cobweb Model and their interrelationships are represented in Figure IV.2. Following the diagram are verbal descriptions of each model relationship, and a listing of the equations used to represent each relationship quantitatively within the simulation model. The number within each element of the diagram indicates the relevant section and equation set in the text. Several different compilers, including FORTRAN, could be employed in analyzing the model. However, DYNAMO is generally best suited for the study of dynamic behavior in economic systems. It is specifically designed to represent the feedback loop structures which determine behavior, and it is extremely efficient. The computer time for one simulation of

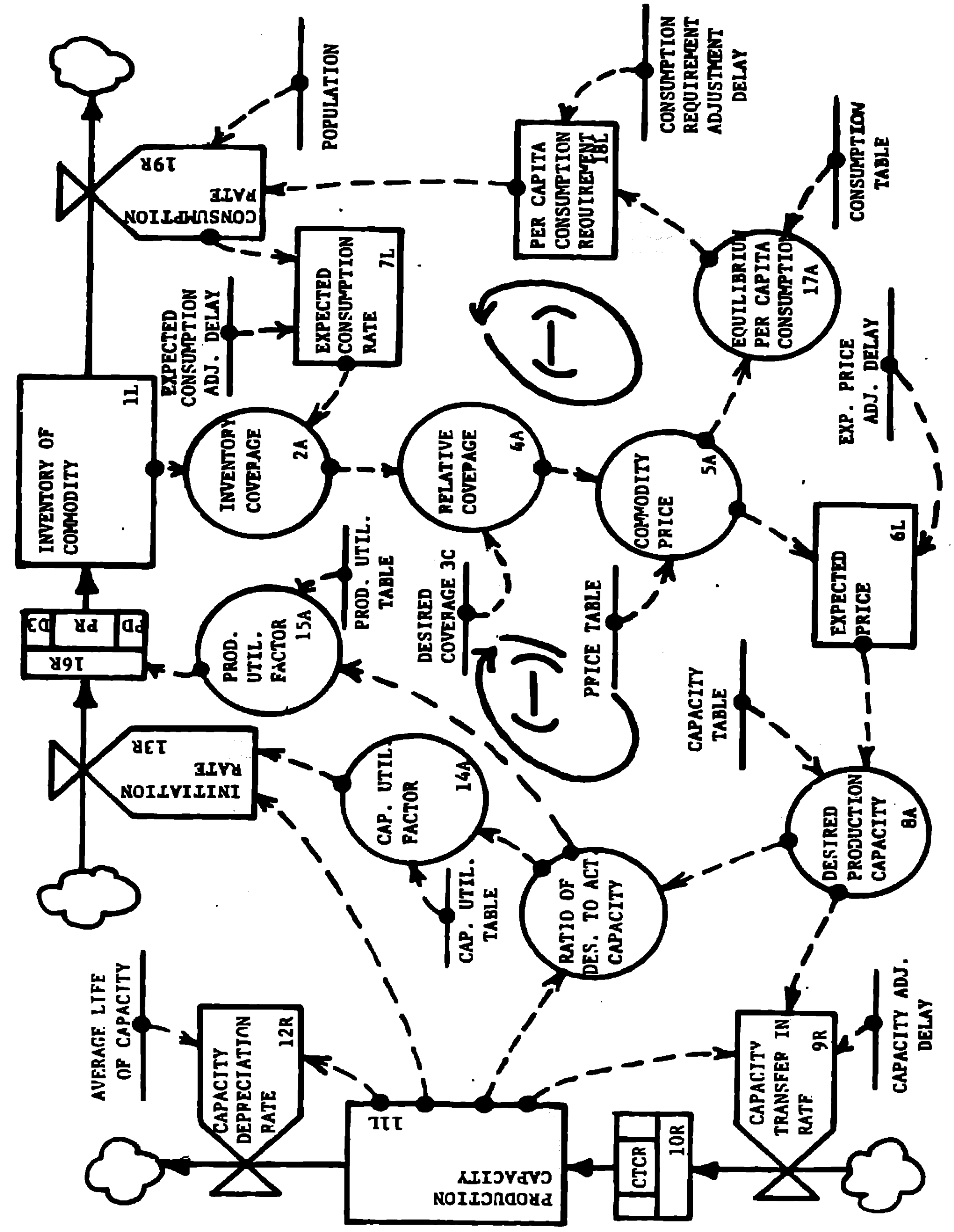


Figure IV.2; DYNAMO Flow Diagram of the Dynamic Cobweb Model

(This page may be folded out for reference) a typical economic model would cost about $.50. Thus we will represent the model relationships in equations compatible with DYNAMO.[1]

Dynamic Cobweb Model - Verbal and Quantitative Description

1. Inventory -

In every commodity system there will be stocks of the product in several physical forms and in many locations. It is assumed in the basic model that only the combined magnitude of all inventories is important in the long run behavior of the system. Further, only production and consumption determine that combined level. Theft, dumping, spoilage, etc. are not represented in the basic model.

```
INV.K=INV.J+(DT)(PR.JK-CR.JK)
INVN=6000
     INV    - INVENTORY OF COMMODITY      (UNITS)
     PR     - COMMODITY PRODUCTION RATE   (UNITS/MONTH)
     CR     - CONSUMPTION RATE            (UNITS/MONTH)
     INVN   - INITIAL VALUE OF INVENTORY  (UNITS)
```

The initial value for inventory refers to no specific commodity. In presenting the basic model we will specify hypothetical, but realistic, values for all constants and tabular relationships.

---

[1] An appendix lists the total model equations. A complete explanation of DYNAMO is given in (Pugh; 1963 and 1968).

2. Coverage -

Those holding stocks of the commodity are concerned with the length of time current inventory would satisfy anticipated demand. Coverage is simply the ratio of current inventory to expected consumption rate.

```
COV.K=INV.K/ECR.K
     COV    - INVENTORY COVERAGE             (MONTHS)
     INV    - INVENTORY OF COMMODITY         (UNITS)
     ECR    - EXPECTED CONSUMPTION RATE      (UNITS/MONTH)
```

3.&4. Desired and Relative Coverage -

Inventories play several functions. They protect intermediate processors from the cost of idle capacity should their supply of commodity be interrupted. They stabilize the price which processors must charge to recover the average cost of their product.[2] As inventory increases, however, the costs of storage, facilities maintenance, personnel expenses, spoilage, and interest charges all rise, while the protection afforded by each additional unit decreases. The marginal stockout yield and the marginal carrying cost are qualitatively represented in Figure IV.3.

---

[2] For a comprehensive discussion of inventory costs and a quantitative theory of the inventory-price relation see (Weymar; esp. pp.32-59).

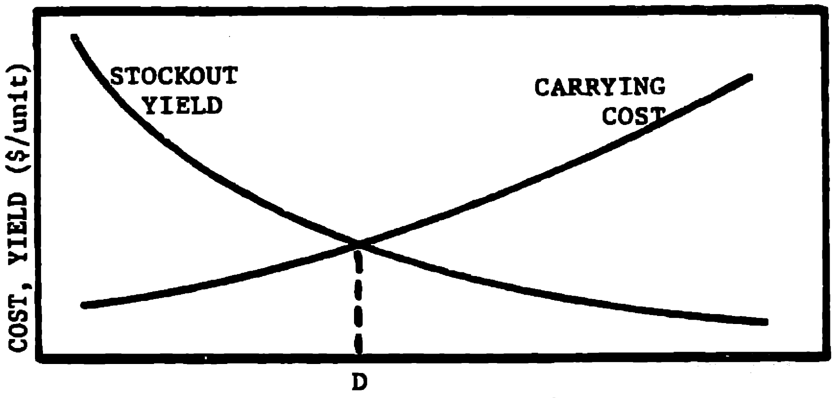


Figure IV.3: Marginal Cost and Yield of Inventory

Those holding stocks will prefer to hold that amount "D" which just equates the marginal cost and yield of the inventory. The level of the stockout yield depends upon the magnitude of fluctuations in the system. With smaller production cycles, a given quantity of inventory is more likely to protect against production interruptions. As fluctuations decrease the stock out yield curve would thus shift to the left, lowering the economically optimum, desired coverage. However, desired coverage would be essentially constant over the course of one production cycle and, it will be assumed constant in the Dynamic Cobweb Model. In Chapter VII we will discuss an important implication of desired coverage's longer term dependence upon the magnitude of fluctuations in the system.

In actual systems, distributors may hold some of their commodity stocks as future contracts. The Dynamic Model assumes that there is no futures market, and that all inventory must be held as physical stocks. Since cycles existed before there were widespread futures markets, futures transactions and price information can not be essential components of the cycle. Where it becomes desirable to study the impact of a futures market on system stability, the desired coverage relationships could easily be modified. This has been done for different purposes in (Weymar).

Actual coverage is compared with that desired to determine the relative coverage afforded by current stocks

```
DCOV=1.0
RCOV.K=COV.K/DCOV

    RCOV  - RELATIVE INVENTORY COVERAGE   (DIMENSNLESS)
    COV   - INVENTORY COVERAGE            (MONTHS)
    DCOV  - DESIRED INVENTORY COVERAGE    (MONTHS)
```

5. Price -

Whenever the relative coverage is greater than 1.0, it will pay those holding stocks to decrease their inventories. They will correspondingly lower the commodity price in an attempt to discourage production and stimulate consumption. The converse is also true. Price will be increased when the relative coverage falls below 1.0. Price is thus determined by relative coverage.

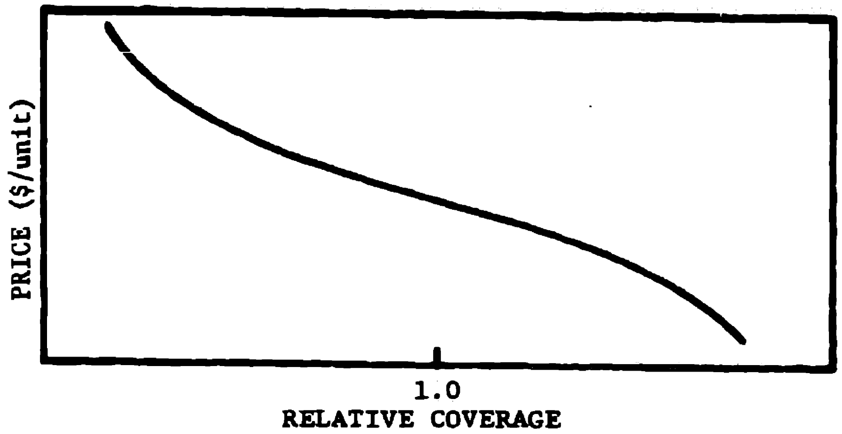


Figure IV.4: Relative Coverage-Price Relationship

```
PRICE.K=TABLE(PTAB,RCOV.K,0,1.998,.333)
PTAB=100/94/80/50/20/10/0
    PRICE  - COMMODITY PRICE              (DOLLARS/UNIT)
    PTAB   - PRICE TABLE                  (DOLLARS/UNIT)
    RCOV   - RELATIVE INVENTORY COVERAGE  (DIMENSNLESS)
```

In actual commodity systems there are, of course, several different prices: price received by producers, by processors, and by distributors, i.e., that charged the consumers. Where there are more than a few competitors, however, these different prices are generally highly correlated. Their differences will be unimportant in determining the long-term dynamics of the system. Like the Static Cobweb Model, then, the Dynamic Cobweb Model assumes only one price. We will acknowledge separate, though linearly related, producer and consumer prices when the parameter values of the basic model are changed to represent the hog system.

6. & 7. Expectations -

Given the history of consumption and price fluctuation in commodity systems, producers will tend to discount recent changes in either parameter. We adopt the model of producer expectations proposed by Nerlove and presented in Chapter III.[3] The current rate of change in the expected value is proportional to the difference between recent

---

[3] Though first proposed in the context of commodity analysis by Nerlove, this formulation is merely the process of exponential smoothing. The expected i.e. forecast, value is simply a weighted average of all past actual values, with greater weights placed upon the more recent data.

expected value and recent actual value.

$$EV.K = EV.J + (DT)(B)(AV.J - EV.J)$$

The inverse of B is a measure of the time required for a producer to adjust his expectations to a change in the actual value.[4] We thus define an "expectation adjustment delay" equal to B' for each expectation process.

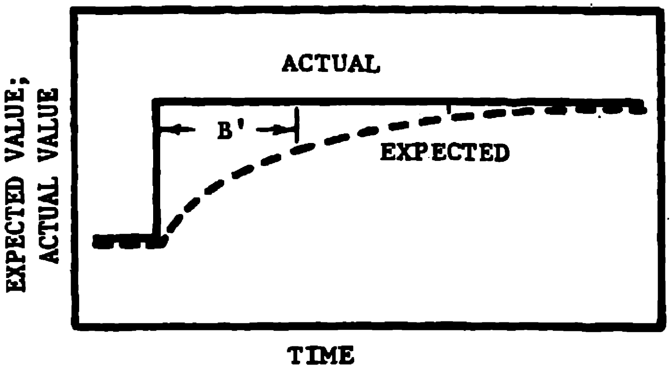


Figure IV.5: Response of Expectations to Change in Actual Parameter Value.

```
EP.K=EP.J+(DT)(PRICE.J-EP.J)/EPAD

EP=EPN

EPN=50

EPAD=3

     EP    - PRICE EXPECTED BY PRODUCERS  (DOLLARS/UNIT)
     PRICE - COMMODITY PRICE              (DOLLARS/UNIT)
     EPAD  - EX. PRICE ADJUSTMENT DELAY   (MONTHS)
     EPN   - INITIAL VALUE OF EX. PRICE   (DOLLARS/UNIT)
```

---

[4] Where exponential smoothing is used, B' is the time required for the expectation process to reduce by 63% the difference initially caused by a step change in the actual value.

```
ECR.K=ECR.J+(DT)(CR.JK-ECR.J)/ECAD

ECR=ECRN

ECRN=600

ECAD=100

    ECR    - EXPECTED CONSUMPTION RATE     (UNITS/MONTH)
    CR     - CONSUMPTION RATE              (UNITS/MONTH)
    ECAD   - EX. CON. RATE ADJ. DELAY      (MONTHS)
    ECRN   - IN. VALUE OF EX. CON. RATE    (UNITS/MONTH)
```

8. Desired Production Capacity -

Associated with each expected price is a unique desired production capacity. The relationship reflects decreasing marginal returns and the assumption that there is no backward bending supply relationship.

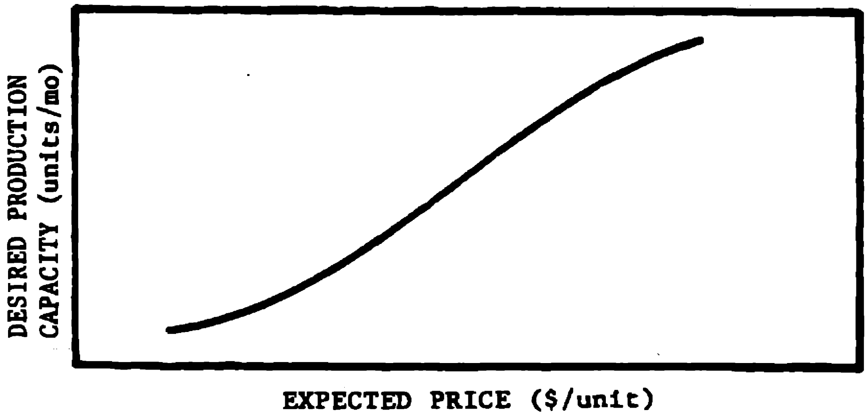


Figure IV.6: Expected Price-Desired Production Capacity

```
DPCAP.K=TABLE(CATAB,EP.K,0,100,20)

CATAB=0/40/200/1000/1200/1280

     DPCAP - DESIRED PRODUCTION CAPACITY  (UNITS/MONTH)
     CATAB - CAPACITY TABLE               (UNITS/MONTH)
     EP    - PRICE EXPECTED BY PRODUCERS  (DOLLARS/UNIT)
```

Desired capacity is an equilibrium concept. It specifies the amount of capacity which would be maintained in the long-run if the price were to remain at its currently expected level. However, there are constraints on the rate at which producers may profitably acquire (or dispose of) productive capital. Two processes, capacity ordering and capacity arrival, intervene between a change in desired production capacity and a corresponding change in actual production capacity.

9. Capacity Transfer Initiation Rate -

Additional resources will generally be required to initiate any increase or decrease in productive capacity. Competition for those resources - personnel, finances, physical facilities - will prevent producers from immediately acting to re-establish capacity at the new desired level. Instead, resources will be diverted to the tasks of transfer, i.e., to construction, to the search for customers, to the purchase of new machinery or facilities, etc., in proportion to the difference between that capacity which is desired and that which is already available or being transferred. The degree of competition for the necessary resources determines the transfer initiation delay, i.e., the time period required by producers to initiate transfer on sufficient capacity to eliminate the current difference.

```
CTIR.KL=(DPCAP.K-PCAP.K-CBT.K)/CTID

CTID=3

     CTIR  - CAP TRANSFER INITIATION RATE (UNITS/MO/MO)
     DPCAP - DESIRED PRODUCTION CAPACITY  (UNITS/MONTH)
     PCAP  - PRODUCTION CAPACITY          (UNITS/MONTH)
     CBT   - CAPACITY BEING TRANSFERRED   (UNITS/MONTH)
     CTID  - CAP TRANSFER IN. DELAY       (MONTHS)
```

Software restrictions prevent direct reference to the contents of the transfer delay. Thus, an additional level, capacity being transferred, is defined to contain at all times the same quantity as the transfer delay.

```
CBT.K=CBT.J+(DT)(CTIR.JK-CTCR.JK)

CBTN=(CTID(DPCAP-PCAP))/(1+CTID)

     CBT   - CAPACITY BEING TRANSFERRED   (UNITS/MONTH)
     CTIR  - CAP TRANSFER INITIATION RATE (UNITS/MO/MO)
     CTCR  - CAP TRANSFER COMPLETION RATE (UNITS/MO/MO)
     CBTN  - INITIAL VALUE OF CBT         (UNITS/MONTH)
     CTID  - CAP TRANSFER IN. DELAY       (MONTHS)
     DPCAP - DESIRED PRODUCTION CAPACITY  (UNITS/MONTH)
     PCAP  - PRODUCTION CAPACITY          (UNITS/MONTH)
```

10. Capacity Transfer Completion Rate -

That capacity which has been ordered or earmarked for disposal will not immediately alter the rate at which new commodity is initiated. Construction, or shipping, or maturation, or conversion, etc., must be completed before that capacity becomes or ceases to be utilized.

Capacity disposal may generally be enacted more quickly than acquisition. In the general model, however, we treat the processes as if they were symmetric.

```
CTCR.KL=DELAY3(CTIR.JK,CTD)

CTD=4

     CTCR  - CAP TRANSFER COMPLETION RATE (UNITS/MO/MO)
     CTIR  - CAP TRANSFER INITIATION RATE (UNITS/MO/MO)
     CTD   - CAPACITY TRANSFER DELAY       (MONTHS)
```

11. Production Capacity -

One often measures capacity in terms of the production rate it could sustain at full utilization. Refinery capacity is measured, for example, in barrels per day. We adopt a similar convention in the basic model, and measure capacity in units/month. Models of specific commodities will, of course, express capacity in units appropriate to that commodity: sows, acres, trees, etc. Capacity will be influenced by two flows: capacity transfer completion and capacity depreciation.

```
PCAP.K=PCAP.J+(DT)(CTCR.JK-CDR.JK)

PCAPN=600

     PCAP  - PRODUCTION CAPACITY          (UNITS/MONTH)
     CTCR  - CAP TRANSFER COMPLETION RATE (UNITS/MO/MO)
     CDR   - CAPACTIY DEPRECIATION RATE   (UNITS/MO/MO)
     PCAPN - INITIAL VALUE OF PROD. CAP.  (UNITS/MONTH)
```

12. Capacity Depreciation Rate -

Whatever the nature of the production capacity, orchards, livestock, acreage, mineral seams, machinery, etc., it will have some average life.

Depletion, biological aging, or physical deterioration will act to depreciate the potential of a stock of productive capital. The rate of depreciation will equal, on the average, the total amount of capacity divided by the average capacity life. Although average life will sometimes depend upon the rate of utilization, we assume it to be a constant in the basic model.

```
CDR.KL=PCAP.K/ALPC

ALPC=200

    CDR    - CAPACTIY DEPRECIATION RATE     (UNITS/MO/MO)
    PCAP   - PRODUCTION CAPACITY            (UNITS/MONTH)
    ALPC   - AVERAGE LIFE OF PROD. CAP.     (MONTHS)
```

13. Initiation Rate -

Where capacity is measured in "units/time", as in the basic model, initiation rate simply equals production capacity multiplied by the capacity utilization factor.

```
INR.KL=(PCAP.K)(CUF.K)

    INR    - COMMODITY INITIATION RATE      (UNITS/MONTH)
    PCAP   - PRODUCTION CAPACITY            (UNITS/MONTH)
    CUF    - CAPACITY UTILIZATION FACTOR    (DIMENSNLESS)
```

14. & 15. Utilization Factors

In the production of most primary commodities the major components of total production costs are fixed. Utilization of the capacity costs relatively little more than merely maintaining it. As explained in Chapter II (p. 19), there may even be penalties associated with suspending production. Thus, producers will tend to initiate production (breeding, excavation, planting, etc.) at the maximum rate permitted by their capacity. Only where there is a great difference between actual and desired capacity may the capacity be used at other than 100 percent of normal production rate. Pesticides, fertilizer, overtime help and marginal capital may be used to increase slightly the amount of product which is initiated. Even after production is essentially completed, producers may have the option of harvesting, refining, etc. more intensely. If desired capacity is far below that actually available, some capacity may simply be left idle or the finished product may be left unharvested or may be destroyed or deployed outside the commodity system. One may distinguish between those actions employed before and after the production process. The first affects the utilization of available capacity, the second affects the use of the finished product. It is initially assumed that utilization does not vary.

```
CUF.K=TABHL(CUTAB,RDAC.K,0,1.998,.333)

     CUF   - CAPACITY UTILIZATION FACTOR  (DIMENSNLESS)
     CUTAB - CAPACITY UTILIZATION TABLE   (DIMENSNLESS)
     RDAC  - RATIO OF DES. TO ACT. CAP.   (DIMENSNLESS)

RDAC.K=DPCAP.K/PCAP.K

CUTAB=1/1/1/1/1/1/1

     RDAC  - RATIO OF DES. TO ACT. CAP.   (DIMENSNLESS)
     DPCAP - DESIRED PRODUCTION CAPACITY  (UNITS/MONTH)
     PCAP  - PRODUCTION CAPACITY          (UNITS/MONTH)
     CUTAB - CAPACITY UTILIZATION TABLE   (DIMENSNLESS)


PUF.K=TABLE(PUTAB,RDAC.K,0,1.998,.333)

PUTAB=1/1/1/1/1/1/1

     PUF   - PRODUCTION UTIL. FACTOR      (DIMENSNLESS)
     PUTAB - PRODUCTION UTILIZATION TABLE (DIMENSNLESS)
     RDAC  - RATIO OF DES. TO ACT. CAP.   (DIMENSNLESS)
```

16. Production Rate

The Static Cobweb Theorem acknowledges a lag between initiation and final availability, i.e. production, of the commodity, but the delay is assumed to be in the form of a pipe-line.

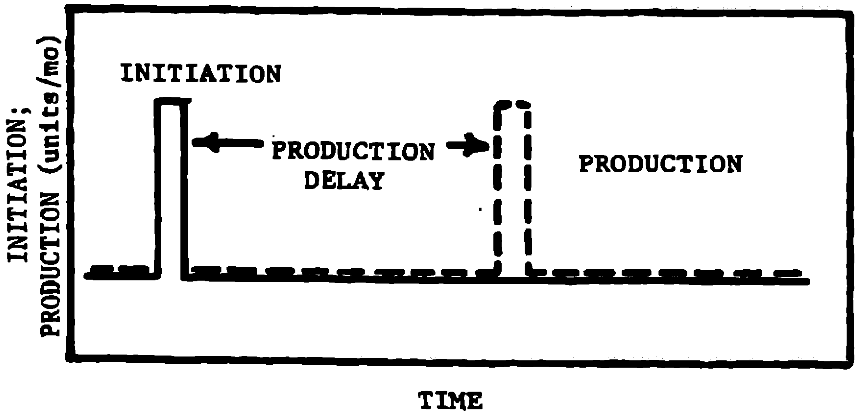


Figure IV.7: Static Relation between Initiation and Production

Because several biological, physical, and meteorological factors will determine the length of the production delay for any given commodity, the delay is probably not so constant in length. The Dynamic Model assumes that the production resulting from some earlier initiation at time "t" will be distributed over a relatively short interval centered about "t + PD" (Figure IV.8).

```
PR.KL=DELAY3(INR.JK,PD)*PUF.K
PD= 6

     PR     - COMMODITY PRODUCTION RATE     (UNITS/MONTH)
     INR    - COMMODITY INITIATION RATE     (UNITS/MONTH)
     PD     - PRODUCTION DELAY              (MONTHS)
     PUF    - PRODUCTION UTIL. FACTOR       (DIMENSNLESS)
```

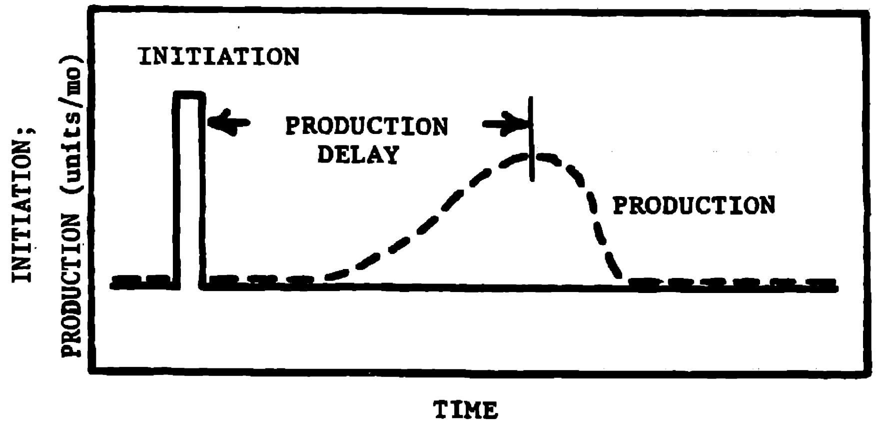


Figure IV.8: Dynamic Relation Between Initiation and Production

17. Equilibrium Per Capita Consumption

In most of its uses a commodity will have one or more competitors. Lead, copper, and aluminum; pork, beef and lamb; rice and wheat all compete in numerous applications. As the price of a commodity increases, it will be found economical to replace it in more and more applications. At any given price there will be certain uses for which the commodity is still the cheapest alternative and other uses in which it is displaced. The relation between commodity price and the demands for uses in which it is optimum at that price defines a long-run equilibrium per capita consumption function. There is some suggestion that long-run consumption is also dependent upon the variance as well as the mean of a commodity's price. However, that relationship is a very minor factor in long-term commodity cycles and is thus eliminated from the basic model.[5]

---

[5] If we were primarily interested in the absolute level of commodity price rather than its fluctuations, this factor would have to be included in the model.

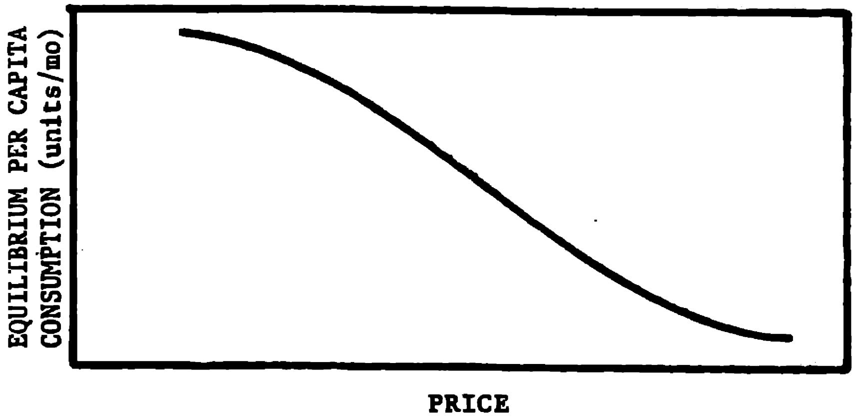


Figure IV.9: Price-Equilibrium Per Capita Consumption Relation

```
EPCC.K=TABLE(COTAB,PRICE.K,0,100,20)
COTAB=7/6.5/5/1/.3/0
    COTAB - CONSUMPTION TABLE             (UNITS/MAN-MO)
    PRICE - COMMODITY PRICE               (DOLLARS/UNIT)
    EPCC  - EQUI. PER CAPITA CONSUMPTION  (UNITS/MAN-MO)
```

18. Per Capita Consumption Requirements

Several factors prevent consumption from adjusting immediately to a change in commodity price. Since consumers do not shop continuously, it will take them some time to recognize that a new commodity price prevails. Where a commodity is used as an intermediate, i.e., is an input in the manufacture of a more refined product, product design or process technology may force some delay in taking advantage of a new relation between the prices of competing commodities.[6] Thus, we define a per capita consumption requirement which adjusts continuously toward the equilibrium per capita consumption defined by the current price. The speed of adjustment, governed by psychological, physical, and technological factors, is a function of the consumption requirements adjustment delay.

```
PCCR.K=PCCR.J+(DT)(EPCC.J-PCCR.J)/CRAD

PCCRN=3

CRAD=9

     PCCR  - PER CAPITA CONSUMPTION REQS. (UNITS/MONTH)
     CRAD  - CONSUMPTION REQS. ADJ. DELAY (MONTHS)
     PCCRN - INITIAL VALUE OF PCCR        (UNITS/MONTH)
```

19. Consumption Rate

Consumption rate is the product of per capita consumption requirements and the Population of consumers, assumed constant in the basic Dynamic Model. We add to the consumption rate equation an additional input which will be used to simulate the impact of exogenous influences on the system.

```
CR.KL=(POP.K)(PCCR.K)(INPUT.K+1)

POP=200

     CR    - CONSUMPTION RATE              (UNITS/MONTH)
     POP   - POPULATION OF CONSUMERS       (MEN)
     PCCR  - PER CAPITA CONSUMPTION REQS.  (UNITS/MONTH)
     INPUT - EXOGENOUS INPUT TO CONSUMP.   (DIMENSNLESS)
```

---

[6] The distinction between long-run and short-run demand is often obscured in economic studies. An excellent discussion of the two functions with statistical estimates of adjustment delays for meats is presented in (Tomek & Cochrane).

These nineteen assumptions constituted the basic Dynamic Cobweb Model. Alternative and additional assumptions can easily be added, but, as I demonstrate below, these relationships are sufficient to produce in simulations the long term cycles characteristic of actual commodity systems.

The equations above together with control cards and a specification of the input functions are included as Appendix I.

Preliminary Analysis of the Dynamic Cobweb Model

Before we base any interpretive or normative statements on our analyses of this model, it is important to obtain some measures of its validity. The concept of validity is discussed in the next chapter. Here we need only recognize a minimum requirement: the model must exhibit the behavior we seek to study. That qualitative test may be administered by subjecting the model, initially at equilibrium, to the same sort of exogenous disturbance employed in Static Cobweb analyses. We simply increase the consumption over a brief period and monitor the systems' subsequent behavior through computer simulation of the model. The resulting behavior over a 150 month period is shown in Figure IV.11 Three model parameters are plotted:

1-Initiation Rate
2-Production Rate
3-Price

These parameters are equivalent to the hog cycle parameters which are presented in Figure IV.10 for comparison:

1-Pig Crop
2-Slaughter Rate
3-Price

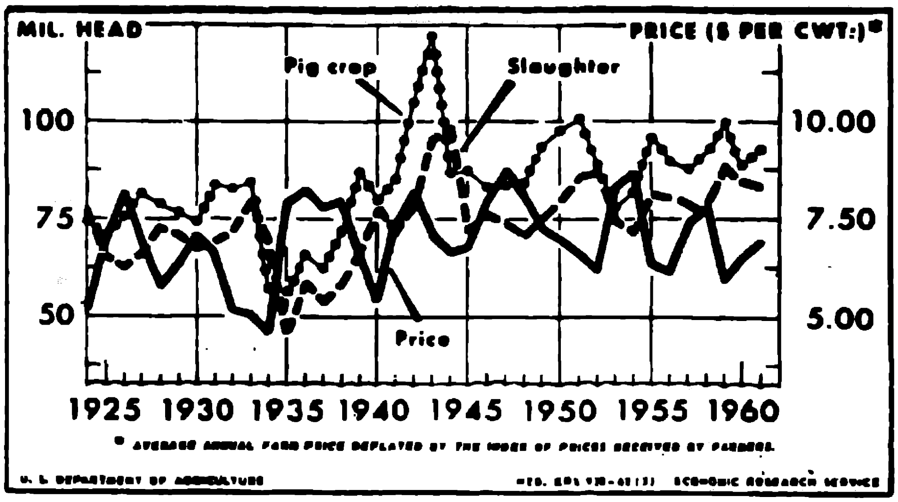


Figure IV.10: Phase Relationships in the U.S. Hog Cycle

In the simulation, the system is initially at equilibrium. Consumption equals production and there is thus no change in inventory or price. Then exogenous inputs increase the consumption rate by a factor of fifty percent from the fifth through the tenth month. Because production does not increase immediately, inventory decreases and the price rises. Higher prices lower consumption and stimulate investment in production capacity resulting eventually in greater initiation and production rates after the ninth and the twelth month respectively. Investment in capacity and the removal of the extra, exogenous consumption in month ten combine to give excess production

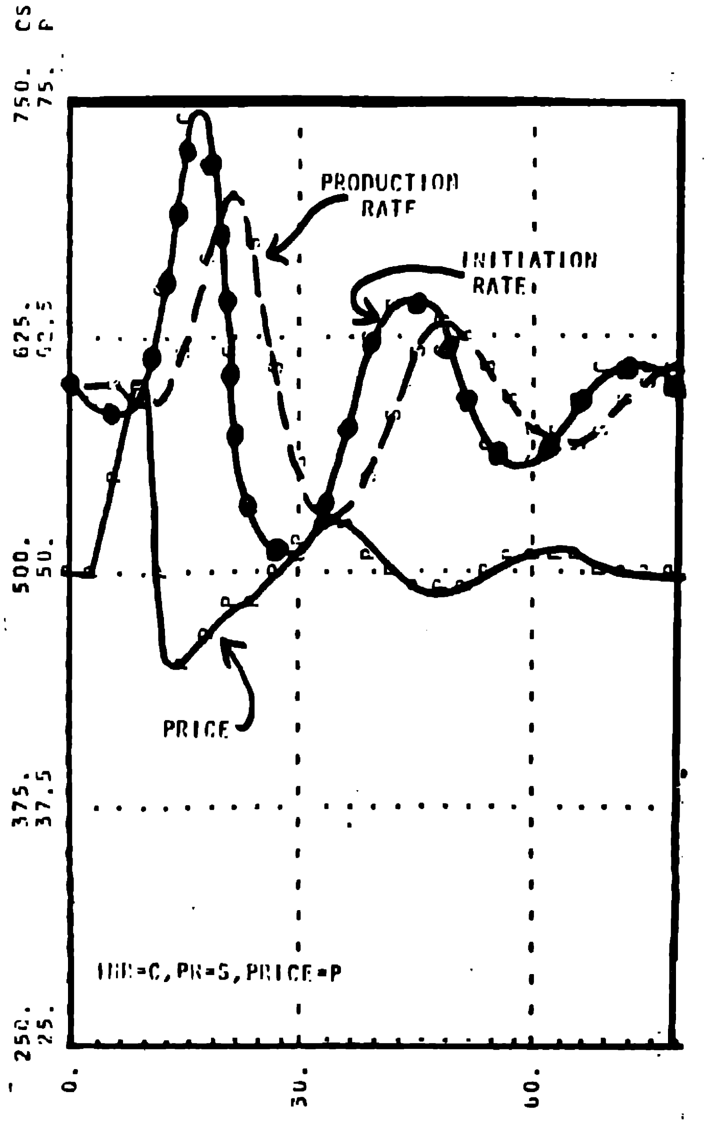


Figure IV.11: Phase Relationships of the Dynamic Model in Response to a Brief Increase in Consumption Requirements

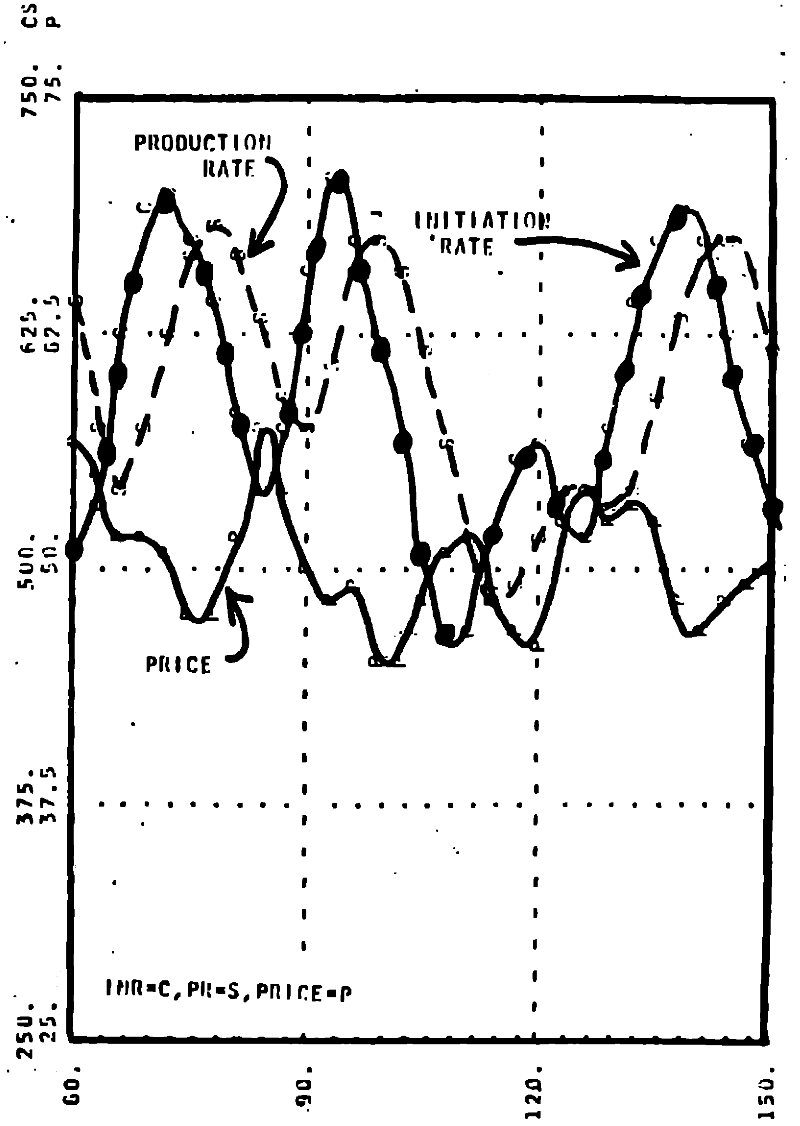


Figure IV.12: Phase Relationships of the Dynamic Model in Response to Noise in Consumption Requirements which reaches a peak in month twenty-one. At this point, however, production is substantially greater than consumption and price is thus too low to support the installed capacity, which consequently begins to decrease. The production sector over-reacts, however, and disposes of too much capacity to support consumption at the normal, equilibrium price of $50.00/unit. Capacity and initiation rate thus begin to increase after the twenty-seventh month and a typical production cycle ensues.

Notice the marked similarities between the simulated and the actual cycles. Peaks in the initiation rate (pig crop) slightly lead those in production rate (slaughter rate), and each rate in the latter pair is always 180° out of phase with price in its system through all cycles.

The differences in scale are not inherent in the structure of the simulation model, but result primarily from the choice of initial values in the Dynamic Cobweb Model. There are, however, three apparent differences between the actual and the simulated time series. First, fluctuations exhibited by the model are damped, the damping factor appears to be about 0.6, while the fluctuations in the real system appear to be sustained. Second, the real world parameters are more erratic than those in the model. Simulated price changes quite smoothly over time. Third, the period of the model fluctuations is only about sixty percent as large as in the actual system: twenty-seven months vs. forty-eight months.

The first two discrepancies derive from the difference in the nature of the exogenous inputs to the real and the simulated system. A disturbance of the form and magnitude employed in static analyses and in the simulation above would seldom be found in actual commodity systems. Instead of a single pulse there is a constant sequence of brief, small, random disturbances, noise, impinging on each relationship in the system.

It is impossible to analyze the influence of noise in the context of the Static Cobweb Model. In the Dynamic Model we may easily include a noise component in the consumption rate. The results of this change, illustrated in Figure IV.12, eliminate the first two discrepancies without altering the similarities in the phase relationships of the actual and the simulated cycles.

The period is the attribute which most differentiates one commodity's production cycle from another's. The period is determined by the structure of the commodity's production and consumption relationships and by the specific value of each parameter in that structure. We would not expect that a set of randomly chosen parameter values would produce the exact periodicity of a real commodity cycle, even if the supply-demand structure were similar to the actual system. However, if both the structure and the parameter values of a model resemble those of the real system, the periods should also be equal.

While the simulated behavior of the Dynamic Cobweb Model is qualitatively similar to the one we wish to understand, the model might still omit several relationships essential in the study of actual commodity production cycles. To test that possibility we change the value of each parameter in the Dynamic Model to represent a specific commodity. To the extent the simulations then exhibit the periodicity of the actual system we will have confidence in the conclusions derived from further analyses of the model.

CHAPTER V

TEST OF THE DYNAMIC COBWEB THEOREM - THE U.S. HOG CYCLE

Brief Comments on the Concept of Model Validity

Cohen and Cyert (p. 119) list three steps in the use of simulation models for economic analyses:

1) Formulation of an appropriate structure
2) Estimation of parameters
3) Test of model validity

Of the three, the last has been the greatest source of confusion. An excellant discussion of validation for socio-economic models is presented by (Forrester; 1961, pp. 115-129, 430-436). Several of his points will be summarized here. No useful model is completely valid, for a model would not be useful unless it were a simplification of reality. Validity is thus a relative concept at best. Because random influences are important determinants of behavior in socio-economic systems, the accuracy of point predictions for individual parameters in the system is not a very useful criterion of model validity. We must rely instead on a comparison of the dynamic behaviors of the model and the real system. Phase relations, relative magnitudes, periods, and rates of parameter change are important.

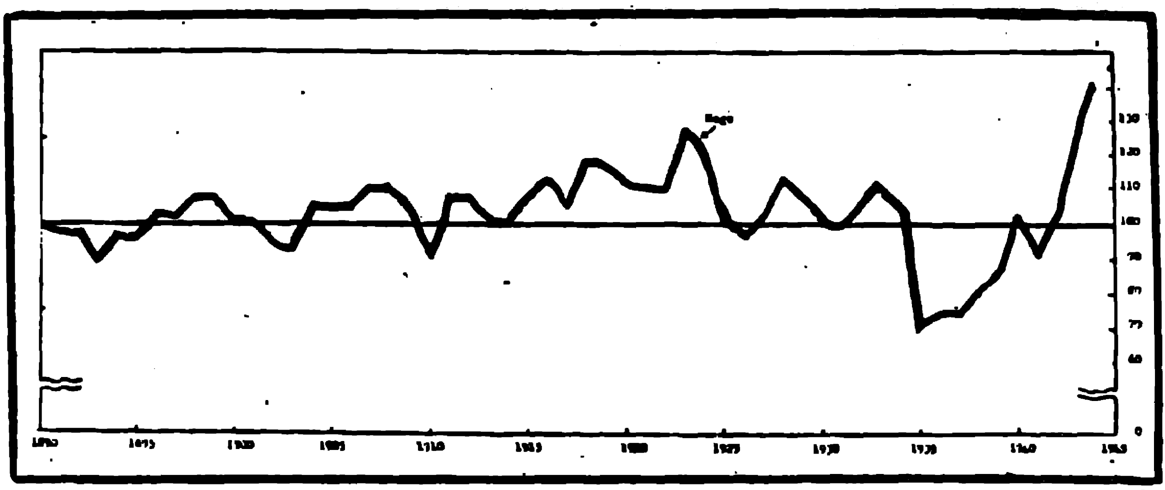
Administrators formulate models for help in solving problems. It appears more fruitful, therefore, to discuss the utility of any given model. Models are useful to the extent that they explain problems and facilitate the search for solutions. Complex system problems are generally expressed in terms of some undesirable behavior phenomenon. A minimum requirement for utility is thus that the model exhibit the same behavior phenomena it has been constructed to explain. Of course, a model must pass that test without including any assumptions which are not at least characteristic of the system being modeled.

Specifically, if the Dynamic Cobweb Model is to be useful in studying the stabilization of long term commodity fluctuations we should expect it to exhibit in simulations the long-term periodicity and phase relationships characteristic of any specific commodity represented by its coefficient values and tabular functions. We have chosen the U.S. hog industry from 1950-1965 as a basis for this test. There is abundant data available on the system, and it exhibits very distinctive four year cycles whose source has long been the subject of debate. Moreover, the hog system is generally the example selected to illustrate the utility of the Static Cobweb Theorem (see, for example, Samuelson, pp. 484-486). Adaptation of the Dynamic Model to the same system will permit, in Chapter VII, a direct comparison of the two theorems.

The Hog Cycle

The hog cycle illustrates the phenomenal ubiquity and tenacity of behavior patterns derived from simple feedback structures. The instability of hog systems was noted as early as a century ago. In an 1876 article, Samuel Brenner declared the "advance and decline" in the value of hogs to be "for twenty years past ... as alternately certain as the diurnal revolutions of the earth upon its axis..." (cited in Breimyer; 1959, p. 760). Tinbergen, one of the original formulators of the Static Cobweb Theorem, illustrated his analysis with reference to a statistical analysis of the German hog cycle presented in (Hanau). There was spirited debate during the thirties about the causes of the hog cycle in Great

Britain (Coase & Fowler, 1935a, 1935b, 1937), (Cohen & Barker). The hog cycle in the United States has received attention in every decade since the forties (Breimyer)(Lorie)(Harlow). Until recently, the U.S. hog cycle was generally thought to be the result of the essentially random fluctuations in corn supplies. Hog feed is one of the largest and most flexible uses for corn. Since demand for pork products is relatively price inelastic and inventories of frozen and cured pork are necessarily small, hog production has been directly tied to corn output. There were continuous, and pronounced hog production cycles between 1890 and 1940, but they varied in length from three to six years (Figure V.1)

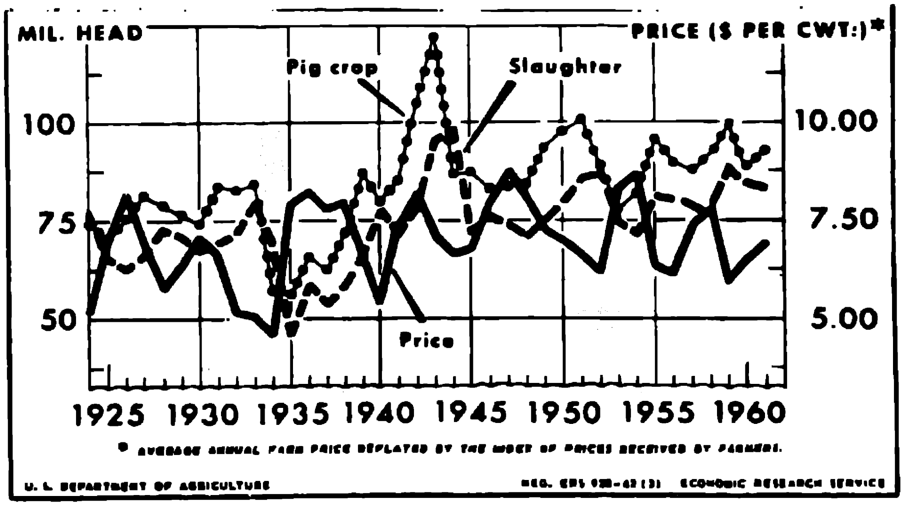


Source: (Lorie; p. 67)

Figure V.1: A Measure of the U.S. Hog Cycle - 1890 to 1944; Index of the Hog Numbers on Farms (Expressed as a percent of trend)

Fluctuations in the price of hogs cause financial hardship for hog producers. When variations in the corn supply were identified as contributing to the instability in hog production, the government began to enact various acreage control and price support programs for corn. Most important of these was the Agricultural Adjustment Act of 1938. With some modifications, it remains in effect today. The program has served to control production, raise prices, and stabilize the supply of corn through the maintenance of inventories. It was expected that the hog production would be stabilized as a result. In fact, the system now exhibits greater fluctuations than it did before. Average annual variations in deflated hog prices (averaged from October through April of each year) rose from 16 percent in the pre-war years to 25 percent in the post-war years (Dean & Heady; p. 845). Figure V.2 illustrates the cycle from 1925 to 1968. The corn support programs were based on too simple a view of the hog supply and demand system. It is not corn price, but the hog-corn ratio which determines the level of hog production. This ratio measures the amount of corn in bushels equal in value to 100 pounds of live hogs. When the ratio decreases, it becomes relatively more profitable to sell corn directly to consumers. When the ratio increases, it is more profitable to feed the corn to hogs and then sell the resulting pork products. The corn programs affected only the denominator of the ratio leaving the price of hogs still free to fluctuate. Thus, short run changes in demand still were possible as temporary imbalances between supply and demand brought changes in the price of hogs and pork. Moreover, the inventories of corn created by the program permitted the stock of hogs to be expanded and contracted more quickly in response to these demand changes.

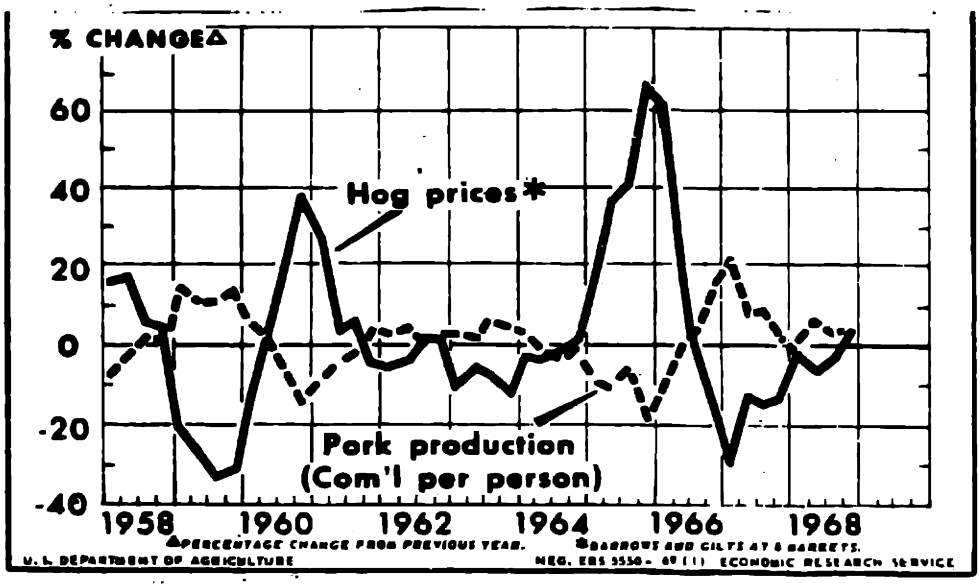
As a consequence, hog fluctuations were not decreased. But as their source shifted from exogenous, random factors, to the endogenous characteristics of the system itself, the cycles did become more regular. A



* AVERAGE ANNUAL FARM PRICE DEFLATED BY THE INDEX OF PRICES RECEIVED BY FARMERS.

U. S. DEPARTMENT OF AGRICULTURE NEG. ERS 930-62 (3) ECONOMIC RESEARCH SERVICE

Figure V.2a: Pig Crop, Hog Slaughter, and Hog Prices



△PERCENTAGE CHANGE FROM PREVIOUS YEAR. *BARROWS AND GILTS AT 8 MARKETS.

U. S. DEPARTMENT OF AGRICULTURE NEG. ERS 5550-69 (1) ECONOMIC RESEARCH SERVICE

Figure V.2b: Changes in Hog Prices and Pork Consumption

Figure V.2: Measures of the U.S. Hog Cycle -- 1925 to 1960, 1958 to 1968 periodicity of about four years began to emerge (Breimyer, 1959).

Since the new cycle could no longer be simply attributed to variations in the corn crop, it intrigued economists where the earlier cycles had not. There is today a diverse economic literature on the characteristics of the supply and demand for pork products. Some of the economists display good qualitative understanding of the factors involved in the cycle (Breimyer), (Haas & Ezekiel), (Lorie). However, quantitative efforts to explain the periodicity and the damping of the cycle in general terms have all begun (and foundered) with the Static Cobweb Theorem. The Static Theorem predicts, as we have shown, that the period of commodity cycles should be about twice the production delay. Hogs have a gestation and growth period of about 11 months. The quantitative literature which deals with the total hog system consists of attempts to rationalize away the two year discrepancy between the observed period and that predicted by the Cobweb Theorem (Harlow) and of models which treat hog production as a unique system (Larson), (Maki). We turn here to the task of formulating a dynamic hog cycle model as a special case of the Dynamic Theorem to determine whether it offers an explanation of the four year cycle.

Adaptation of the Dynamic Cobweb Model to Hogs

Except for several additional biological constants, the model differs from the basic model in only two ways:

(1) Price received by farmers is distinct and different from the commodity's retail price. The two are linearly related.

(2) Any change in production capacity, i.e., breeding stock, alters the production rate directly.

An additional level, mature stock, is inserted between production and inventory. The first order delay formed by this level, mature stock, and mature stock slaughter rate is so short it is dynamically unimportant. However, it portrays the relationships in the real system through which the breeding stock adjustment rate influences the flow of meat into inventory. Similarly, the equivalent of capacity depreciation rate, i.e., old sow slaughter rate, now augments the inventory of commodity. As we will illustrate in analyzing the hog model, these changes have little influence on the long-term dynamics of the system. They are included primarily for realism. The Dynamic Model exhibited long term price-production cycles without these additions and it will be seen that except for its periodicity and damping the hog model behaves similarly to the basic model.

One simplification of the real system will be made in the model. There is in the hog system a strong short term cycle with a period of six months induced by the farmers' marked desire to avoid farrowing their sows in cold weather. The farrowing peaks in May and September (Figure V.3) produce short term fluctuations in slaughter rate and inventory of pork but these tend to be discounted by the producers in making their long term capacity adjustment decisions, thus this short term cycle is not represented in the model.

Statistics used in determining the appropriate parameter values are from issues of <u>Livestock and Meat Statistics</u>, published by the Economic Research Service of the U.S. Department of Agriculture. All relevant series from that publication are included as Appendix II to this thesis. The model's relationships are represented pictorally in Figure V-4. Numerals on each element of the flow diagram again refer to the section in the text which specifies the relevant assumptions. Element names have been adapted from the basic model to conform with common terminology in the hog system.

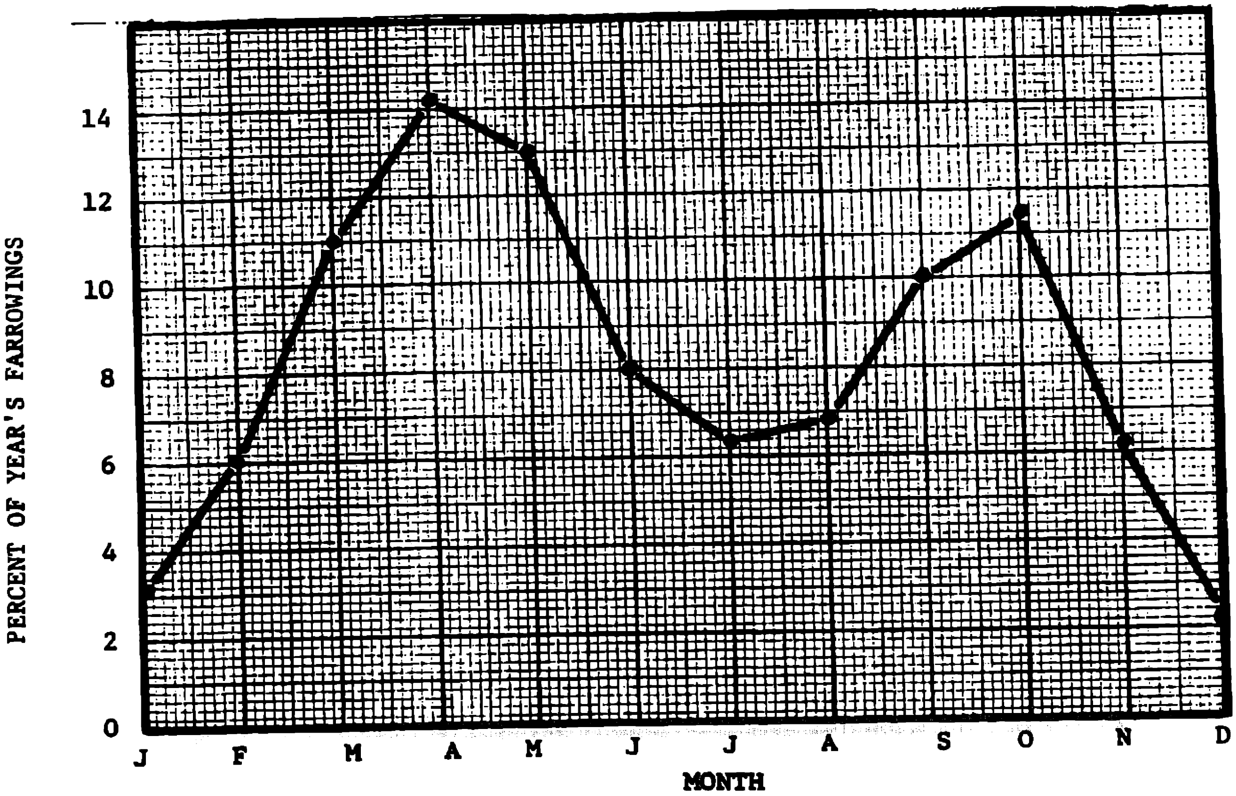


Figure V.3: The Seasonal Characteristics of Hog Farrowings

Dynamic Hog Cycle Model -- Verbal and Quantitative Description

1. Inventory of Pork

There are many organizations involved in the flow of pork products between producers and consumers (Figure IV-5). Each of these entities maintains an inventory of pork in one or more forms. One important set of inventories is the cold storage holdings of frozen and cured pork (HFCP)

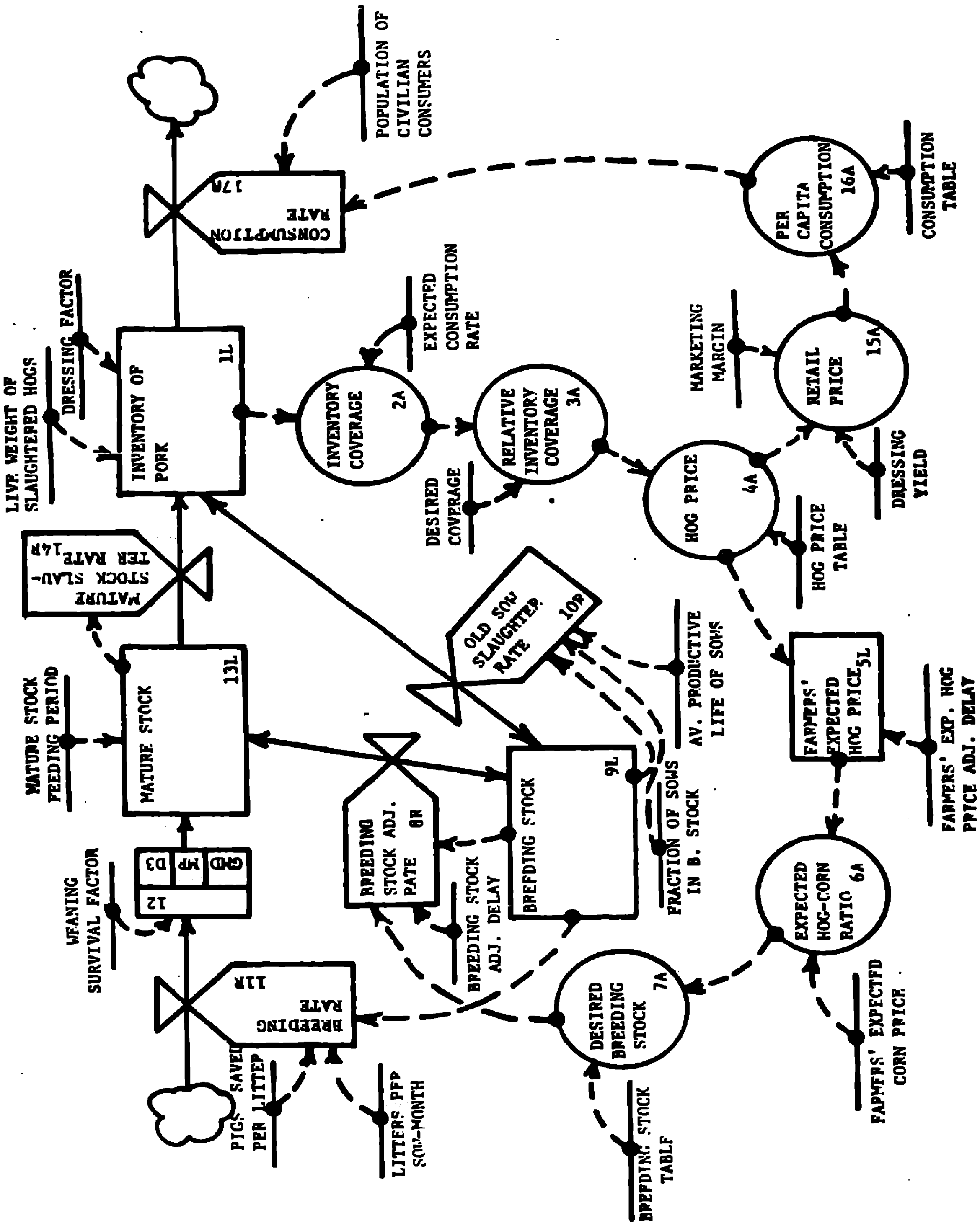
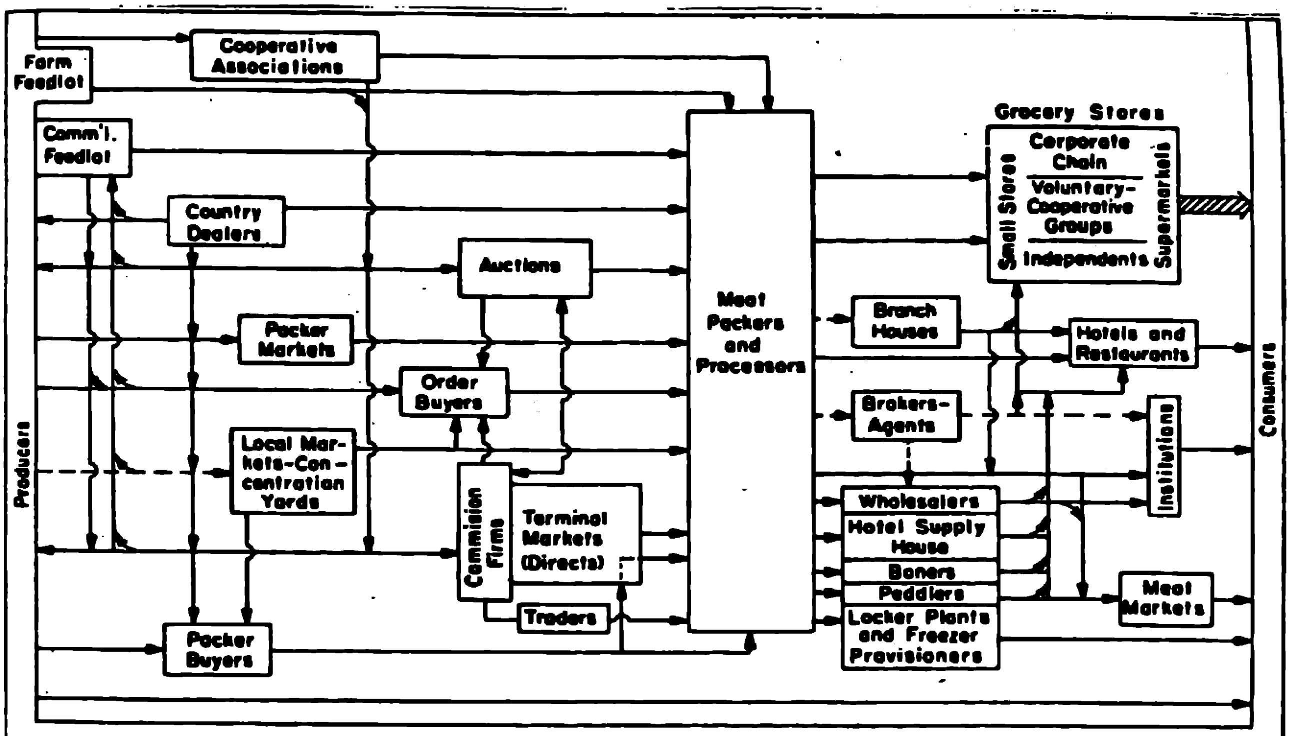


Figure V.4: DYNAMO Flow Diagram of the Dynamic Cobweb Model Adapted to Represent the Hog System

(This page may be folded out for reference with the model description) which are monitored on a monthly basis by the U.S. Department of Agriculture (A.II-1). We assume that this stock represents the total inventory of pork. The model remains valid, however, if there are other stocks of pork whose relative change is the same as that reported for HFCP.



Source (Williams & Stout; p.163)

Figure V.5: Schematic Diagram of Principal Distribution Channels for Livestock and Meat

Imports and exports consistently are less than 2 percent of production (A.II.11c, lines 3 & 4), and they tend to offset each other. Military consumption is also unimportant, only a few percent of the total (A.II-11c, line 6). Thus, we may assume that the inventory of pork is increased only by the slaughter of mature stock and breeding stock and depleted only by the domestic, civilian consumption rate.

The addition to inventory produced by slaughter depends upon the number of hogs slaughtered, their live weight (LWSH), and the percent of each hog which is not discarded as waste during dressing, the dressing yield. A secondary relation has been found between producer price expectations and the live weight of the hogs offered for slaughter (Haas & Ezekiel; pp. 23-25). However, between 1950 and 1966 the average yearly LWSH varied only between 234.8 lbs/hog (1956) and 245.8 lbs/hog (1951) (A.II-2). We therefore assume the live weight of hogs slaughtered to be constant at 240 lbs/hog, its 1961 value. The difference between live and dressed weight can be inferred from three time series: (1) Live Weight of Slaughtered Hogs (A.II-2), (2) Number of Hogs Slaughtered (A.II-7), and (3) Total Pork Production (A.II-11c, line 1).

$$\text{Dressing Yield} = \frac{\text{Total Pork Production (lbs)}}{\text{Total Slaughter (hogs)} * \text{Av. Hog Wt. (lbs/hog)}}$$

The dressing yield has been rising very slowly:

Table V-1: Change in Hog Dressing Yield

Year	Dressing Factor
1950	.552
1955	.561
1960	.577

We assume DY to be constant at .58.

```
IP.K=IP.J+(DT)((MSSR.JK+OSSR.JK)(LWSH*DY)-CR.JK)

IPN=200E6

LWSH=240

DY=.58

    IP     - INVENTORY OF PORK              (LBS)
    MSSR   - MATURE STOCK SLAUGHTER RATE    (HOGS/MO)
    OSSR   - OLD SOW SLAUGHTER RATE         (SOWS/MO)
    LWSH   - LIVE WT. OF SLAUGHTERED HOGS   (LBS)
    DY     - HOG DRESSING YIELD             (DIMENSNLESS)
    CR     - CONSUMPTION RATE               (LBS/MO)
    IPN    - INITIAL VALUE OF IP            (LBS)
```

2. Inventory Coverage -

As in the basic model, inventory coverage is the ratio of current stocks to the expected consumption rate.

```
COV.K=IP.K/ECR

ECR=.99E9

    COV    - COVERAGE PROV. BY INVENTORY    (MOS)
    IP     - INVENTORY OF PORK              (LBS)
    ECR    - EXPECTED CONSUMPTION RATE      (LBS/MO)
```

This ignores the role of futures contracts in providing coverage. However, open interest in pork bellies and hogs has only recently become a significant fraction of the physical holdings, and the phenomenon we seek to explain existed long before the availability of futures contracts.

3. Relative Inventory Coverage

As formulated in the basic model, relative coverage, the ratio of actual coverage to that desired, measures the relative desirability of current inventory levels. If we assume that the average value of inventory coverage over the course of one hog cycle will be that actually preferred by the processors and distributors, we may infer the value of desired coverage. During the four year period from 1955 to 1958, pork production averaged about 813 million pounds per month. The average cold storage holdings of frozen and cured pork reported for that same period was approximately 293 million pounds. We therefore set desired coverage equal to 0.36 months.

```
RCOV.K=COV.K/DCOV

DCOV=.36

     RCOV   - REL COV PROV BY INVENTORY     (DIMENSNLESS)
     COV    - COVERAGE PROV. BY INVENTORY   (MOS)
     DCOV   - DES COV PROV BY INVENTORY     (MOS)
```

4. Hog Price

Prices are continually established at each of three interfaces in the hog system: farmer-processor, processor-distributor, and distributor-consumer. No one of these is solely responsible for prices. Consumers' preferences limit the amount of pork which can be sold at any given retail price; the expectations, economic constraints, and stocks of speculators and processors determine the premium (or discount) they will pay over current prices; and the economics of swine production together with the number of hogs on the farm influence the amount of pork which will be forthcoming at any price. A 1935 study of direct hog marketings indicated that "a rise or decline in hog prices is at least as likely to occur in interior points as at public markets" (Bjorka) Most economists have thus adopted the attitude expressed in a recent text:

> All that can be stated with confidence is that prices among the various kinds and types of markets and market locations are highly interrelated. They are jointly determined by factors which affect all of them and which tie them together into one vast economic system. (Williams & Stout; p. 566)

Like the instinct theory of behavior, this approach explains everything and accomplishes very little. Anyone interested in the design and understanding of a system must attempt to identify the major causal relations. As a working hypothesis we provide here an alternative explanation of price determination based on actual decisions of participants in the system.

The first of the three interfaces listed above is the only one in which one participant has virtually no bargaining power. Farmers have little alternative to selling their mature stock for the best price offered them by processors. We look therefore at the farmer-processor interaction for an explanation of short-term price determination. It will be argued later that retail prices are determined primarily as competition forces essentially constant margins between the initial cost and the retail price of pork. Farmers are at least fortunate that there is intense competition among processors for their product. It has been suggested that no economic system approaches perfect competition as closely as the meat economy (Breimyer; 1961, pp. 10-12). Prices offered to farmers are thus not likely to result from capricious decisions, but will be the result of economic constraints upon the processors. The most important determinants are the underlying price trend and the level of current stocks for pork. Since we are interested in the endogenous determinants of production cycles, we have assumed the price trend to have zero slope. The major factor thus is the current coverage offered by processors' stocks. The important role of these inventories was summarized very well in the report on a 1926 study of hog price determination reported in (Haas & Ezekiel).

> In making bids for hogs, the buyers gave more attention to how large market receipts (i.e., prices) had been running, and how large they were expected to run during the next several months, than they did to the receipts during the single month. At the same time, they had to get their share of the business volume, so during short periods when receipts (of live hogs) temporarily fell below the general average, the competition to get a share of the business forced prices somewhat above the general trend, though not nearly so much as did an equal shortage in supply extending over a considerable period. (pp. 10-11)

> The quantity of hog products in storage is another of the factors which men who are buying live hogs for slaughter take into consideration, as bearing upon the prices they will probably be able to get for the products from the hogs. Large storage stocks represent that much to be added to current production to give the supply of products available for consumption during the next few months; low storage stocks may mean that some of the production of the next few months will be held out of consumption and used to build stocks up to their usual level. For this reason hog slaughterers usually tend to bid somewhat higher for live hogs when the stocks of provisions are low than when they are high. The quantity of hog products in storage had a material influence upon the strength of the demand for live hogs during the period before the war, especially whenever they went more than about 40 percent above the usual quantity in storage for the particular season of the year.

> Next to changes in export demand, change in storage stocks was apparently the most important cause of change in the strength of the market demand. (p. 18)

This study was conducted shortly after World War I, when exports had been a significant fraction of the total U.S. production. Now net exports are less than one percent of production, and export demand is unimportant in determining price.

We have described in Chapter IV the factors which determine the relation between the size of inventory and its cost or value to the processor. It was apparent that coverage, rather than absolute quantity, was the important measure of an inventory's value. Relative coverage was introduced simply to normalize this measure to the economics of any particular commodity.

We have found no study of the relation between relative coverage and hog price, but the precise nature of the relationship must be fairly unimportant. The relationship certainly has changed during the last 90 years, but the dynamics of the hog system have remained essentially unchanged during that period. The approximate relationship can be inferred through analysis of data on cold storage holdings, price received by farmer, and consumption (A.'s II-1, 3, 11). In the actual system desired coverage logically would change throughout the year in relation to the peaks in slaughter, being high just after the fall slaughter peak and low just before it. To eliminate this seasonal component from our calculations we will look at data for one month for each of four years during a hog cycle. We have chosen July, 1955-1968. The calculations are shown in Table V-2 (next page). Since July's inventory tends to be only 80 percent of the average month's holdings' CSH are normalized to get a figure more characteristic of all months.

Table V.2: Hog Price vs. Relative Coverage

DATE	COLD STORAGE HOLDINGS	NORMALIZED HOLDINGS	AV. MO'S CONSUMPTION PREV. YR.	COVERAGE	DES. COVERAGE	RELATIVE COVERAGE	HOG PRICE
July 1955	298	373	837	.43	.36	1.19	16.40
July 1956	307	384	820	.47	.36	1.32	15.30
July 1957	204	255	790	.32	.36	.90	19.30
July 1958	173	216	849	.25	.36	.71	21.70

The empirical relation above is represented in Figure V.6.

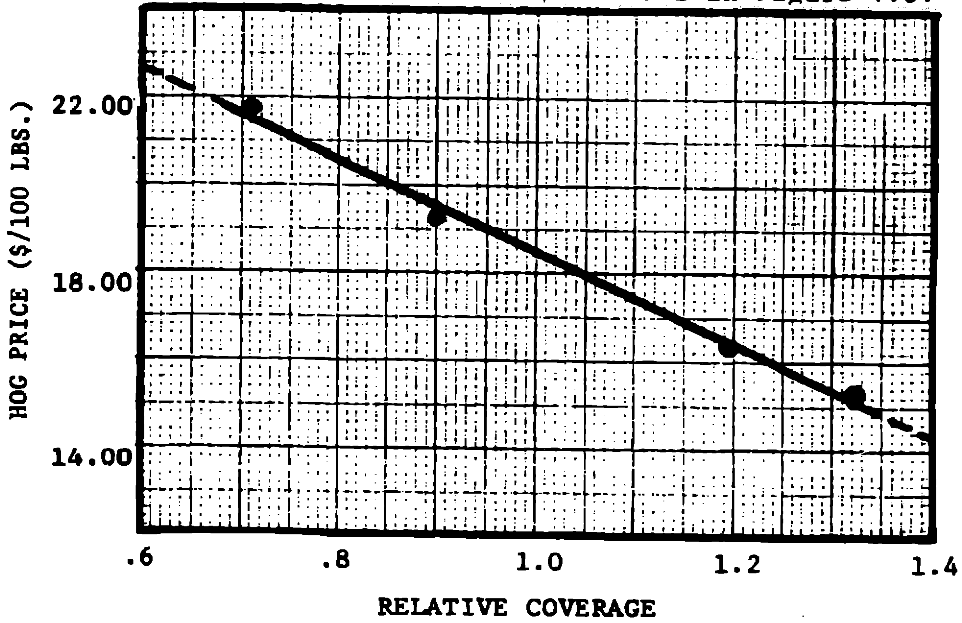


Figure V.6: Hog Price vs. Relative Coverage

```
HP.K=TABLE(HPTAB,RCOV.K,.4,1.6,.4)
HPTAB=24.8/20.6/16.4/12.2

    HP     - HOG PRICE                            ($/100 LBS)
    HPTAB  - TABLE OF HOG PRICES                  ($/100 LBS)
    RCOV   - RELATIVE COVERAGE PROV. BY INVEN.    (DIMENSNLESS)
```

5. Farmers' Expected Hog Price

No part of the Static Cobweb Theorem has received more criticism than the assumption that producers will continue to formulate their price forecasts on the basis of recent prices even after several complete cycles in hog prices. Two different authors have recently addressed this specific assumption in the Theorem.

> ...it is probably not reasonable to suppose that a decision-maker ignores information which is easy to obtain, particularly information which he can obtain by observing his own past behavior. If by observing his own past expectational errors, he can perceive a simple mechanical pattern in these errors, the economist should probably not assume that the decision-maker ignores this information. (Mills; p. 331)

> ...the inviolable assumption that people never learn from experience, no matter how protracted, is at least debatable. (Buchanan; p. 81)

Significantly, neither author cites any empirical evidence to support his claim.

One could postulate numerous alternative assumptions about the manner in which producers forecast future prices for their hogs. We know that exogenous factors such as weather, war, and business cycles exercise some influence on producer price forecasts (Heady & Kalder; p. 35). However, the regularity of hog cycles suggests a dominant endogenous component. The direct empirical evidence which is available does not give overwhelming support to any of the various forecasting models which have been proposed. However, there is general support for the Nerlovian model postulated in the Dynamic Cobweb Model.

A survey of 177 Iowa hog producers in 1947 and 1948 provided information on the formation and revision of their hog price forecasts (Heady

& Kalder). In December, 1947, and again in June, 1948, all producers were asked to give their best guess about the level of hog prices in December, 1948. The history of actual prices and the producers' forecasts are pictured in Figure V.7.

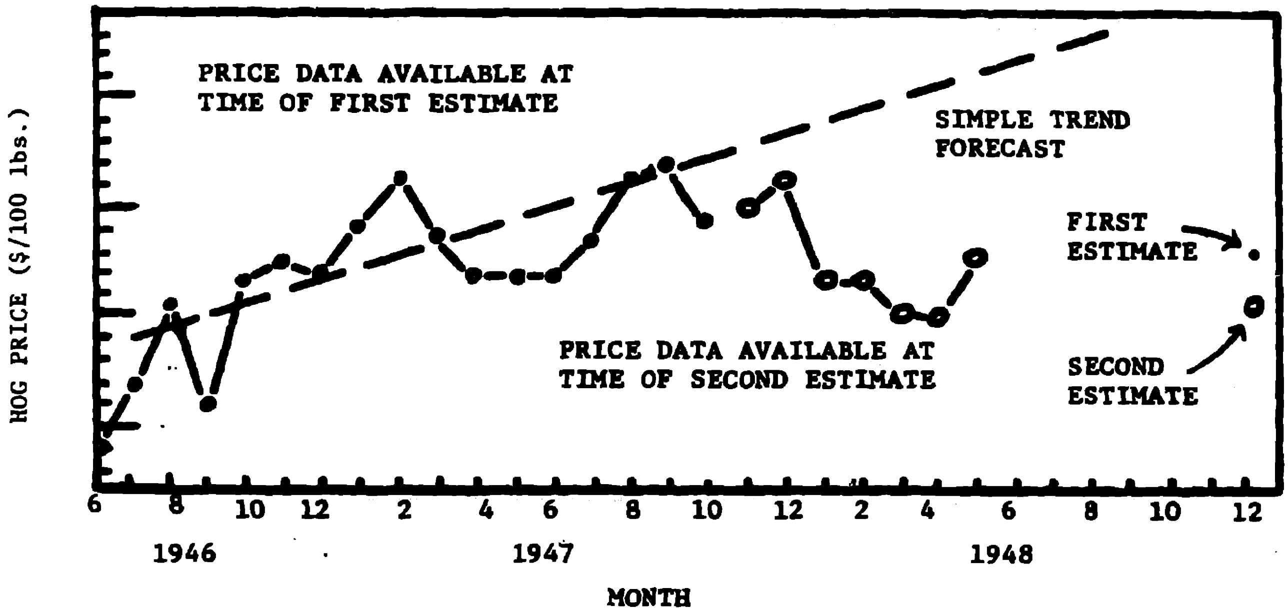


Figure V.7: Actual vs. Expected Hog Prices

In December, 1947, the mean of producers' individual estimates was $22.60; 77.4 percent of the producers forecast a price between $18.00 and $27.80. This dramatically suggests that simple extrapolation was not being used by producers. The simple trend, as shown in the figure, would lead to an estimate of about $33.00 for December, 1948. With the six months of additional data (from December, 1947, through May, 1948) producers revised their previous estimates downward to yield a new mean expected price of $20.19. That revision is also consistent with the Nerlove model.

A 1940 study of hog price expectations in a declining market also suggested that about 80 percent of the producers were averaging recent prices to estimate prices nine months in the future (Schultz & Brownlee; pp. 494-495).

We know that the producers' response to price for hogs is similar to that for other agricultural commodities.

> Changes in livestock (hog) numbers on farms show the same general type of response to antecedent prices received by producers as do changes in crop acreages. (Bean p. 370)

Thus, data on the formation of expectations for other products is relevant here. Exponential averaging apparently does take place in related commodities.

In a survey of 134 farmers, "a comparison of weighted means of long and short term prices with the expectations of the farmers showed that the statistical averages which give heavy weighting to prices in the immediate past were closest approximations to the expected prices for corn and soybeans". (Williams; pp. 23-24).

In a study of corn yield expectations it was found that:

> Farmers would give the average of the last three years' yields about equal weight with the long-term average and, accordingly, would expect future yields to maintain half of the recent gains in yields, ascribing the remainder to an unusual combination of favorable corn seasons. (Schultz & Brownlee; p. 489).

The length of the expectation delay for hogs is somewhat clouded by the presence of the strong farrowing seasonal, for the two marked farrowing peaks are reflected in seasonal price trends. Thus, producers find it necessary to consider current prices in the context of those obtained a year ago. On the average, however, it appears from the data that it takes only four to eight months of prices different from last year's equivalents to persuade producers a new price level will be obtained. We will thus employ a Nerlovian expectation model with B = .16, i.e., the expectation adjustment delay, B, is six months. Setting FEHPAD = 6 means that hog prices occurring more than twelve months earlier are given essentially zero weight:

$$(1 - 1/6)^6 = .0083$$

This assumption is supported by an econometric study of producers' coefficient of expectations, i.e., B, for hog prices. The analysis of yearly figures for hog price, farrowings, etc. found B = 1. Producers were giving no weight to prices one year or more before their breeding decisions (Dean & Heady; p. 856).

```
FEHP.K=FEHP.J+(DT)(HP.J-FEHP.J)/FEHPAD

FEHPN=21.2

FEHPAD=6

     FEHP   - FARMERS' EXPECTED HOG PRICE  ($/100 LBS)
     HP     - LIVE HOG PRICE               ($/100 LBS)
     FEHPAD- FARMERS' EXP HP ADJ. DELAY    (MOS)
     FEHPN - INITIAL VALUE OF FEHP         ($/100 LBS)
```

This formulation neglects the possible influence of futures markets on the decisions of hog farmers, but it has been suggested that the biological and economic characteristics of hogs minimize the utility of futures price information for producers (Skadberg).

6. Expected Hog-Corn Ratio

Feed expenses constitute 75 to 80 percent of the total cost of swine production (Carroll et. al.; p. 199). Thus, expected grain costs are important determinants of the producers' desired breeding stock. Most hogs are corn fed, so that changes in the hog-corn ratio have been found to be the most important determinant of the level of breeding stocks (Brandow),(Dean & Heady), (Warren & Pearson; p. 133-149), (Wright).[1]

As we mentioned briefly in the introduction to this chapter, U.S. government programs have reduced fluctuations in corn prices to the point where they are no longer the most important source of variation in the H-C ratio. The ratio tends now to move primarily in response to hog prices (Figure V-8, next page). Linear regression of hog-corn ratio on hog price for the years 1955 to 1965 shows a correlation of 0.87 Changes in hog price thus accounted for 75 percent of the variance in the value of the ratio over this period. We therefore assume farmers' expected corn price is constant at $1.14/bushel, its average value over the past decade (A.II-4).

---

[1] The Hog-Corn Ratio is defined:

$$\text{H-C Ratio} = \frac{\text{Hog Price (\$/100 pounds live wt.)}}{\text{Corn Price (\$/bushel)}}$$

It is the number of bushels equal in value to 100 lbs. of live hog.

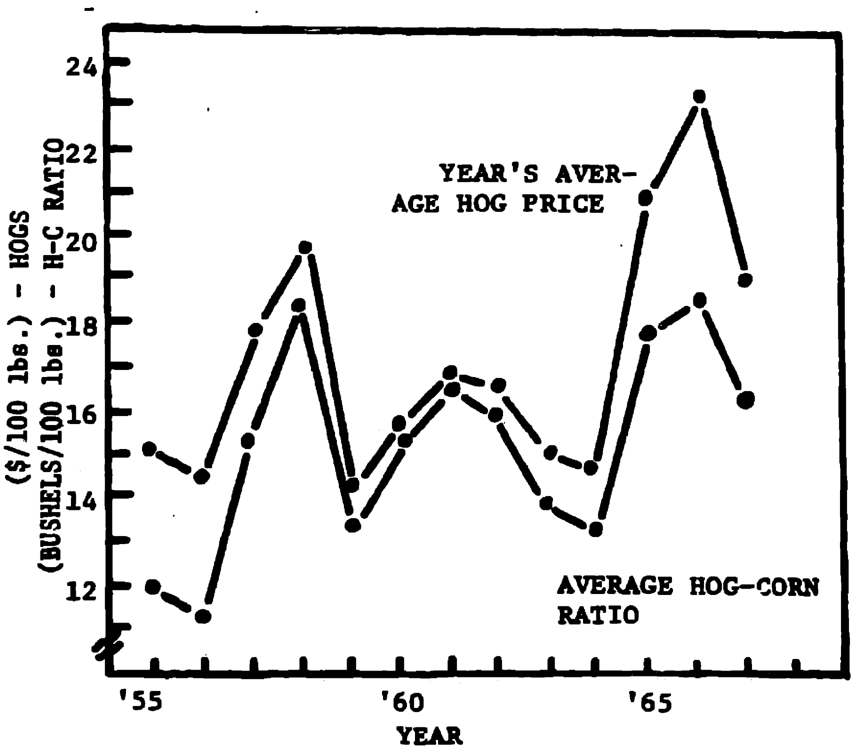


Figure V.8: Hog Price and Hog-Corn Ratio 1955 to 1967

```
EHCR.K=FEHP.K/FECP

FECP=1

     EHCR   - EXPECTED HOG-CORN RATIO      (BSHL/100 LB)
     FEHP   - FARMERS' EXPECTED HOG PRICE  ($/100 LBS)
     FECP   - FARMERS' EXPECTED CORN PRICE ($/BUSHEL)
```

7. Desired Breeding Stock

A study of hog production decisions lends support to our assumption that farmers base their desired level of breeding stock on a Nerlovian-like price forecast.

> The third farmer changed his production from year to year in response to current and past price relations. Five years out of seven the third farmer had fewer hogs to sell when hogs were high in price, and many to sell when hogs were cheap. Most hog farmers vary their hog production in much the same way that this third farmer did. They decide what to do on the basis of the current or past prices, paying no attention to the way such conditions have worked out in previous years. (Haas & Ezekiel; p. 3)

The exact relationship between desired breeding stock and the expected hog-corn ratio will depend upon the marginal cost curves of the individual farmers. Rudimentary economic considerations would suggest a relation in the form of Figure V-9.

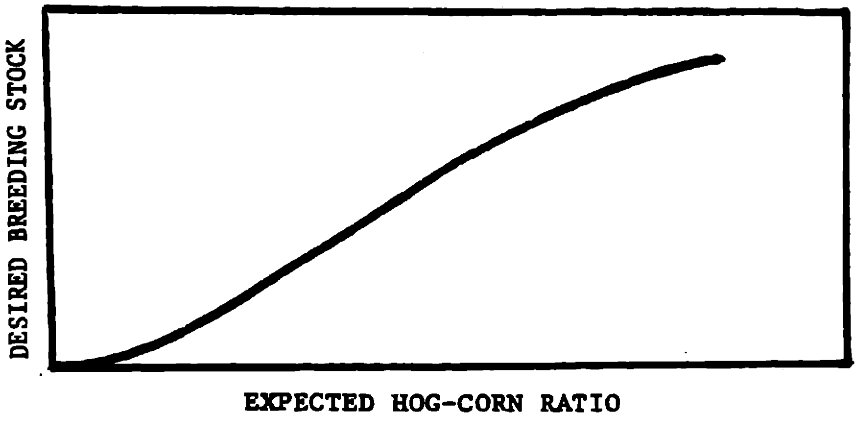


Figure V.9: Probable Relation Between Desired Breeding Stock and Expected Hog-Corn Ratio

We will explicitly rule out the possibility of a backward-bending supply curve.[2] Although the elasticity of supply has been addressed by more

---

[2] For an article which should finally lay this artifact to rest, despite its continuing fascination for static model builders, see (Farnsworth & Jones).

econometric research than any other aspect of the hog system, there is unfortunately little good information on the relation of the hog-corn ratio to long-term equilibrium supply decisions. All econometric models have so far confounded the influence of long-term supply and short-term adjustment constraints. The reported increase in the elasticity of supply (Dean & Heady) probably stems more from decreased adjustment delays than from a shift in the long-term equilibrium production function. A few economists have come to accept the possibility of psychological delays in information processing of price data without apparently recognizing that there may also be other processes and constraints between price and capacity changes.

To infer the approximate relationship we will examine the historical reaction of total spring farrowings to earlier hog-corn ratios. Since all of the breeding stock is bred to farrow sometime during the spring season, data on total number of sows farrowing (A.II.6) gives good data on the actual size of the breeding stock. There is some indication that fall farrowings may be less responsive to changes in the ratio (Dean & Heady).

According to the Dynamic Theorem there is a value of desired breeding stock uniquely associated with each value of expected hog-corn ratio. That value is determined by the marginal cost of all non-corn inputs required in the production of mature stock. If the assumption is correct, the change in breeding stock which follows any specific hog-corn ratio is, in itself, meaningless. One must also consider the initial value of the breeding stock. One could easily get either a positive or a negative change in the breeding stock for any given H-C ratio depending upon whether

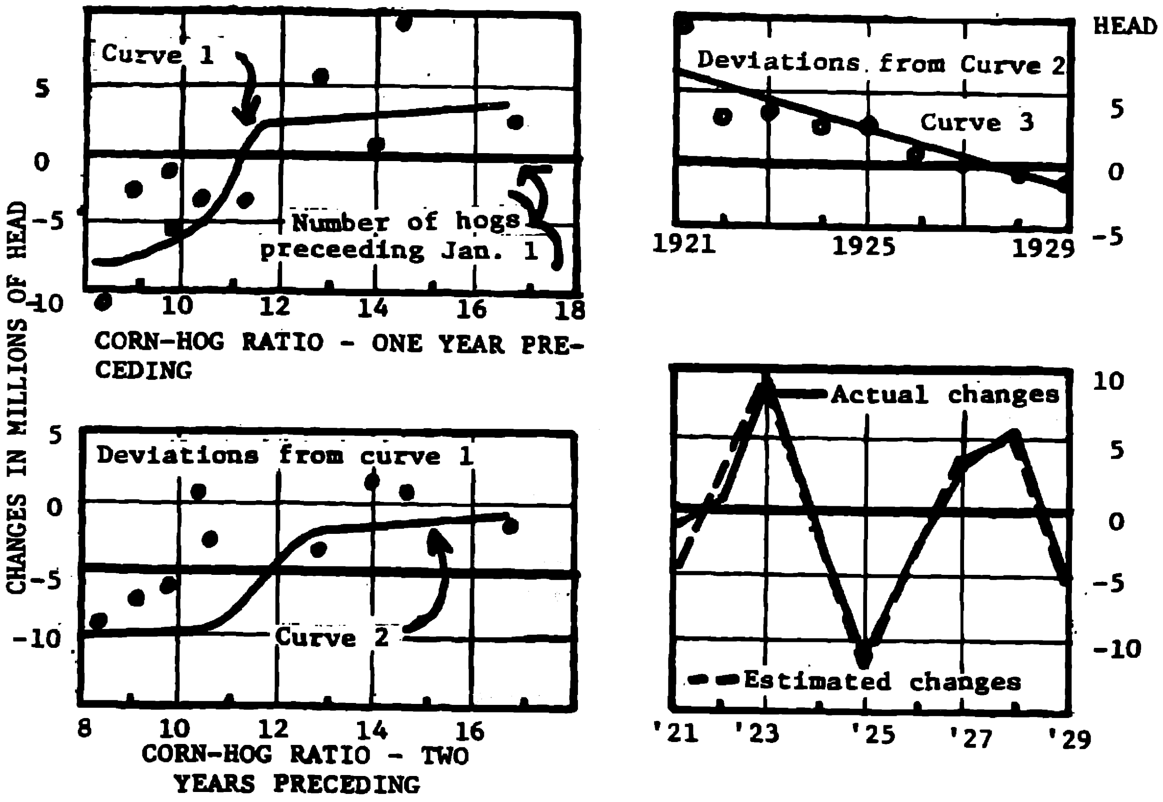


Figure 2. Hogs on Farms: Changes in Number Jan. 1 to Jan. 1 for Years 1921-1929

In Figure 2 a similar analysis is presented for the year-to-year changes in the number of hogs on farms in the United States. The corn-hog ratio for the calendar year was first related to changes in hog numbers between the beginning and end of the year. The changes not accounted for by this price, (as represented by curve 1 in section 1) were then related to the corn-hog ratio for the second twelve-month period prior to the changes in numbers, and finally, the changes not accounted for by this second price series were plotted in section 3 and represented there by a regular downward trend. The extent to which these three curves account for the yearly variations in hog numbers is indicated in the fourth section of Figure 2, where changes computed from these curves are compared with the actual.[3]

Figure V.10: Bean's Analysis of Hog Inventory's Price Response

---

[3] If we assume that it would take three parameters each to describe curves one and two and two parameters to describe curve three, we must give credit to Bean for fitting nine data points with only eight explanatory variables.

the initial value of breeding stock was below or above the desired level. The analysis performed by Bean is thus invalid (Figure V-10). The assumption that a given value of the hog-corn ratio is associated always with a specific change in the breeding stock cannot be correct. If the ratio were held at some constant value other than that for which there is no change (11.2 in Bean's analysis), then breeding stock would continue to increase or decrease linearly and indefinitely according to Bean's theory.

A more fruitful approach should be to plot both the initial and the final value of breeding stock associated with each value of expected hog-corn ratio. If our theory is correct we would expect a result like that shown in Figure V.11:

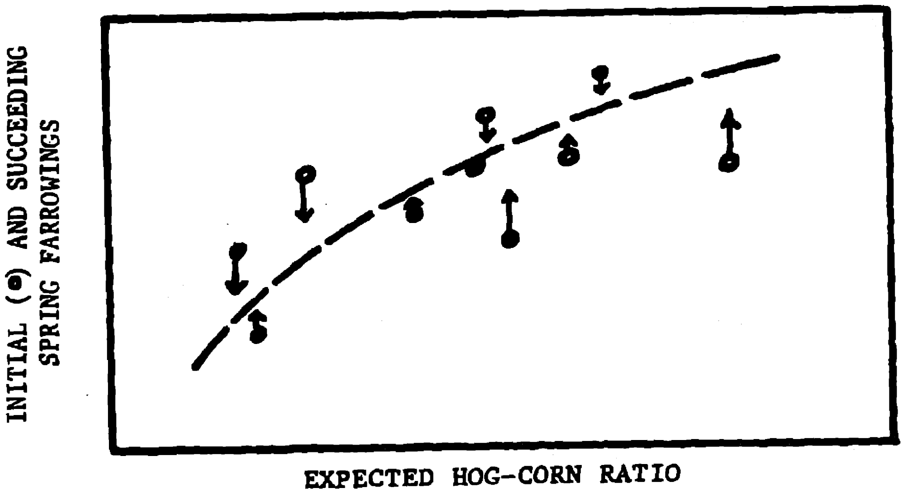


Figure V.11: Expected Relation of Breeding Stock Adjustments to Hog-Corn Ratios

The dashed line denotes the underlying, but unknown, long-run equilibrium supply curve. The tail of each arrow denotes the total breeding stock (i.e. spring farrowings) in year t-1. The head of the arrow denotes the same parameter for year t. Location of the arrow horizontally specifies the hog-corn ratio for the year t-1. We will use this as a measure of the producers' expected ratio. When the initial value of breeding stock is further from the desired level, the change is greater. A full adjustment is not made in one year.

The analysis outlined above was conducted for data from 1956-1966, the result was similar to that predicted (Figure V.12):

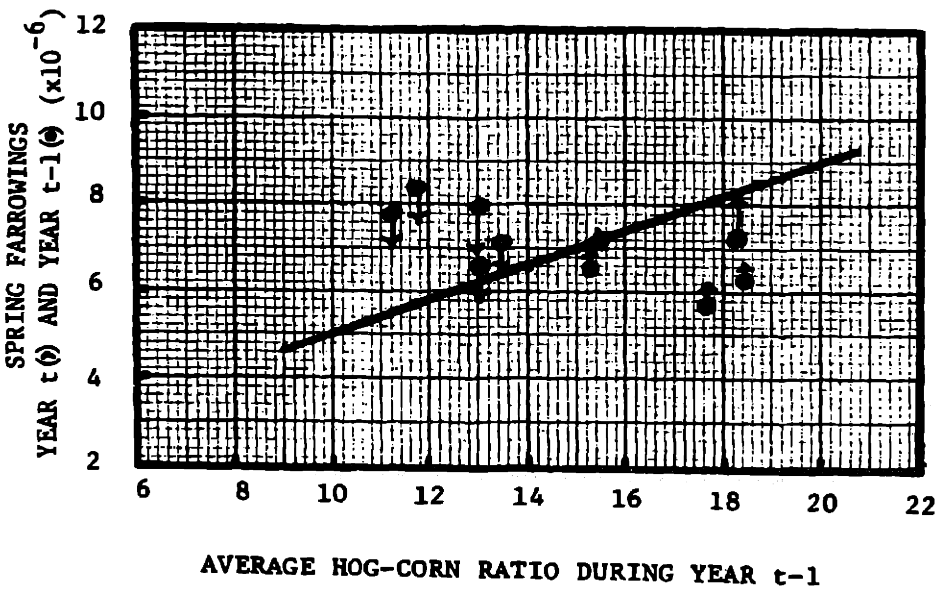


Figure V.12: Empirical Relation of Breeding Stock Adjustments to Hog-Corn Ratios

The solid line indicates a possible underlying desired breeding stock curve. As in any of the table functions, extreme values are not of interest in interpreting past behavior. They would be more important in any attempt to radically redesign the system.

```
DBS.K=TABLE(BSTAB,EHCR.K,10,25,5)
BSTAB=5E6/7E6/9E6/10.6E6
      DBS   - DESIRED BREEDING STOCK          (SOWS)
      BSTAB - TABLE OF BREEDING STOCK         (SOW)
      EHCR  - EXPECTED HOG-CORN RATIO         (BSHL/100 LB)
```

8. Breeding Stock Adjustment Rate

The number of sows and gilts in the breeding stock at any specific time will generally not be exactly that desired by the producer on the basis of his current hog-corn ratio expectations. Comparison of the current breeding stock with that desired indicates the changes in stock level which should eventually should be made. Associated with each level of breeding stock there is a specific quantity and mix of inputs: man-hours, shed or lot space, feed stores, feeding and sanitary equipment, etc., required to maintain that number of swine. Since these inputs are quite flexible, they will generally be released or allocated to other agricultural products when not required in pork production. The delays inherent in re-acquiring those inputs or shifting them between hogs and other uses prevents immediate adjustment of the breeding stock to the level desired. We assume that the effort directed to re-allocating the necessary resources will be proportional to the difference between desired and actual breeding stock. Breeding stock adjustment delay (BSAD) is a measure of the time required to reduce the difference. Conversations with a hog producer suggest that BSAD is approximately five months.

```
BSAR.KL=(DBS.K-BS.K)/BSAD
BSAD=5
```

```
BSAR   - BREEDING STOCK ACQUIS. RATE  (SOWS/MO)
DBS    - DESIRED BREEDING STOCK       (SOWS)
BS     - BREEDING STOCK               (SOWS)
BSAD   - BREEDING STOCK ACQUIS. DELAY (MOS)
```

9. Breeding Stock

Neglecting deaths from disease or injury which make them unsuited for consumption, the number of sows and gilts used in breeding depends only upon the breeding stock adjustment rate and the slaughter of old sows which have outlived their period of efficient production.

Gilts are ready to be bred at about the same time as they would otherwise be slaughtered. Mature stock can thus be diverted to breeding with essentially no delay. Similarly, gilts which have been fed for breeding can be sold for commercial slaughter at only about 20 percent discount. There are consequently no biological delays in switching hogs between mature stock and breeding stock.

```
BS.K=BS.J+(DT)(BSAR.JK-OSSR.JK)
BSN=8.2E6
      BS     - BREEDING STOCK                  (SOWS)
      BSAR   - BREEDING STOCK ACQUIS. RATE     (SOWS/MO)
      OSSR   - OLD SOW SLAUGHTER RATE          (SOWS/MO)
      BSN    - INITIAL VALUE OF BS             (SOWS)
```

10. Old Sow Slaughter Rate

Breeding stocks may consist of sows and/or gilts. Sows are bred until their productivity begins to decrease, gilts are bred once and then finished for slaughter. Each has its advantages. Gilts sell at less discount, offer higher feed efficiency, and give certain tax benefits. However, sows produce larger and heavier litters (Carroll et. al.; p. 127). We assume for purposes of this study that the average productive life of sows is three years, and that the fraction of breeding stock composed of sows is .6. Both values are obtained from a study of farrowing vs. age (Carmichael & Rice; Table 10, p. 87).

```
OSSR.KL=(BS.K*FSBS)/APLS
FSBS=.6
APLS=36

     OSSR   - OLD SOW SLAUGHTER RATE        (SOWS/MO)
     BS     - BREEDING STOCK                (HOGS)
     FSBS   - FRACTION OF SOWS IN B. S.     (DIMENSNLESS)
     APLS   - AV. PRODUCTIVE LIFE OF SOWS   (MOS)
```

11. Breeding Rate

Breeding stock maintenance costs represent approximately one-third the total cost of producing pork (Carroll et. al.; p. 126). Thus, there is high incentive to use the stock at full capacity, i.e. to breed all sows so that they farrow twice a year. If any sows are not required for farrowing, they are transferred to the mature stock and slaughtered.

Slightly more pigs are saved from each spring litter (A.II.6a) than from those in the fall (A.II.6b). The average pigs saved per litter (PSPL) has been rising in each case.

Table V-3: Trend in Pigs Saved Per Litter

Year	Pigs Saved Per Litter	
	Spring, Dec.- May	Fall, June-Nov.
1950	6.41	6.65
1955	6.90	6.81
1960	6.96	7.02
1965	7.22	7.27

We take PSPL to be 7.0

```
BR.KL=BS.K*LPSM*PSPL

LPSM=.17

PSPL=7.0

     BR      - BREEDING RATE                    (HOGS/MO)
     BS      - BREEDING STOCK                   (SOWS)
     LPSM    - LITTERS PER SOW-MONTH            (LIT/SOW-MO)
     PSPL    - PIGS SAVED PER LITTER            (PIGS/LITTER)
```

12. Gestation and Maturation Delay

The delays involved in obtaining mature stock for slaughter are illustrated in Figure V-13.

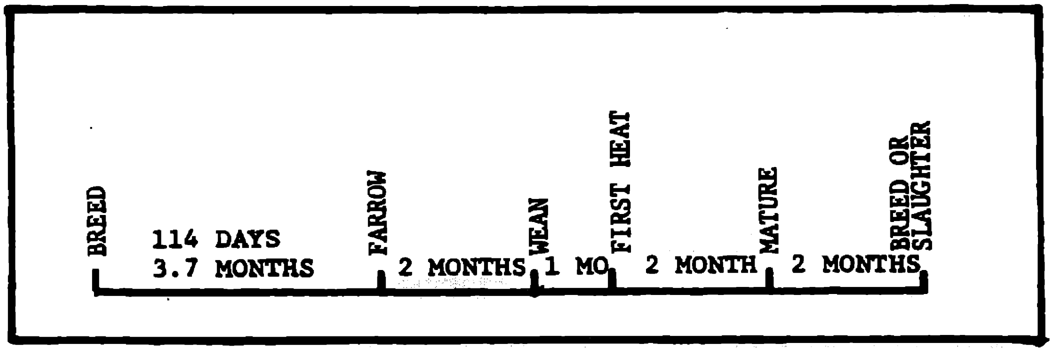


Figure V.13: Gestation and Maturation Delays

Ninety percent of all farrowings take place between 111-119 days after breeding (Carmichael & Rice; p. 68). Pigs are weaned at about two months, and sows come into heat for the first time about one month later. Best practice, however, is to wait until the sow has reached around 250 pounds before first breeding it.[4] This takes about six months from weaning. Hogs generally are slaughtered at about the same age. We thus define a gestation-maturation delay between breeding and addition to mature stock. GMD is a third-order delay of eleven months.

Even after birth, there is a fairly high attrition among young pigs. One study revealed that only 69.9 percent of all pigs born alive live to be weaned (Carroll et. al.; p. 138). To reflect this factor we introduce a weaning survival factor equal to 0.7.

```
MR.KL=(DELAY3(BR.JK,GMD))*WSF
GMD=10
WSF=.7
     MR     - MATURATION RATE               (HOGS/MO)
     BR     - BREEDING RATE                 (HOGS/MO)
     GMD    - GESTATION-MATURATION DELAY    (MOS)
     WSF    - WEANING SURVIVAL FACTOR       (DIMENSNLESS)
```

13. Mature Stock

Mature stock is composed of those hogs in the terminal stage of feeding and preparation either for slaughter or for addition to the breeding stock. The primary source of mature stock is those pigs bred ten months

---

[4] This information was provided by the staff of the animal husbandry department of Rutgers University.

earlier. However, when breeding stock adjustment rate is negative, mature stock will be incremented by those sows and gilts not currently required for breeding.

```
MS.K=MS.J+(DT)(MR.JK-MSSR.JK-BSAR.JK)

MSN=13E6

     MS     - MATURE STOCK                  (HOGS)
     MR     - MATURATION RATE               (HOGS/MO)
     MSSR   - MATURE STOCK SLAUGHTER RATE   (HOGS/MO)
     BSAR   - BREEDING STOCK ACQUIS. RATE   (SOWS/MO)
     MSN    - INITIAL VALUE OF MS           (HOGS)
```

14. Mature Stock Slaughter Rate

The rate at which mature stock is slaughtered depends upon the number of mature swine and the average mature stock feeding period. Feed expenses constitute 75 to 80 percent of total costs in swine production, and efficiency of feeding goes down with age and weight (Figure V.14, next page). Since heavier hogs also sell at a discount, producers can not economically delay slaughter by more than two months. Grain very soon costs more than the marginal value of the meat it produces. Most mature swine will have been slaughtered by the end of their first month after entering the category of mature stock. The mature stock feeding period is thus set at two months.

```
MSSR.KL=MS.K/MSFP

MSFP=2

     MSSR   - MATURE STOCK SLAUGHTER RATE   (HOGS/MO)
     MS     - MATURE STOCK                  (HOGS)
     MSFP   - MATURE STOCK FEEDING PERIOD   (MOS)
```

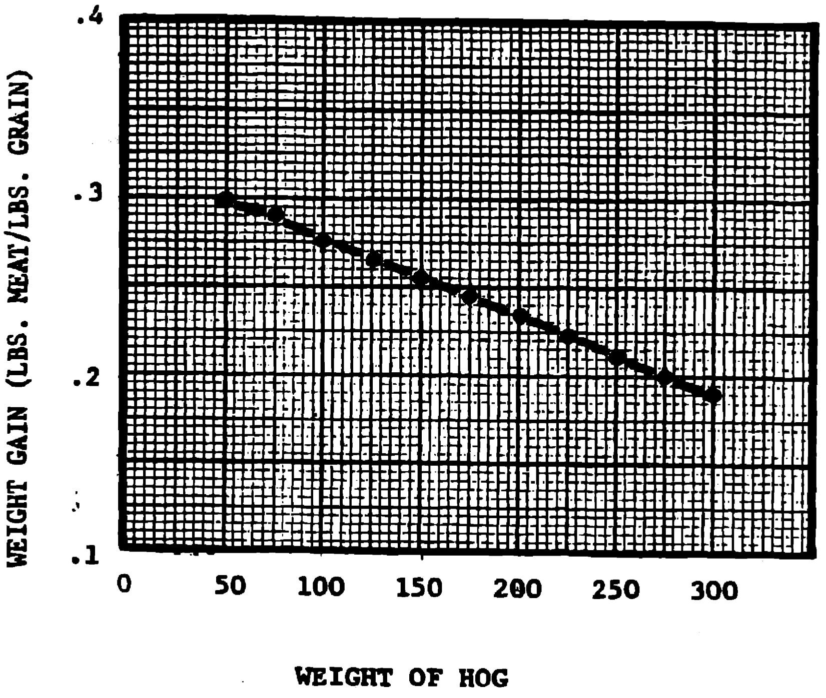


Figure V.14: Marginal Efficiency of Hog Feed

15. Retail Price

Due to the weight loss in processing meat, the production cost (i.e. farmers' receipts) for each pound of meat sold at retail is 1.75 times the original hog price, i.e., hog price/dressing factor. All processors' and distributors' receipts must be added to that. The margin between production cost and retail price of each pound sold at retail has a small seasonal component (Figure V-15). However, its primary determinants are long term trends in the unit costs of labor and other marketing inputs and trends in the amount and kinds of services rendered by the intermediate handlers of pork. We would expect margins to remain fairly constant. During the period of our interest there was, in fact, little change:

Table V.4: Marketing Margins for Pork

Year	Production cost -- Retail Price Margin
1957	27.00
1958	27.90
1959	29.80
1960	27.10
1961	27.80
1962	28.10

Source: Appendix V.8

We thus set retail price equal to the production cost of meat plus a constant marketing margin equal to $.28/lb. retail.

```
RP.K=(HP.K/DY)+MM
MM=28
      RP     - RETAIL PRICE                    ($/100 LBS)
      HP     - LIVE HOG PRICE                  ($/100 LBS)
      DY     - HOG DRESSING YIELD              (DIMENSNLESS)
      MM     - MARKETING MARGIN                ($/100 LBS)
```

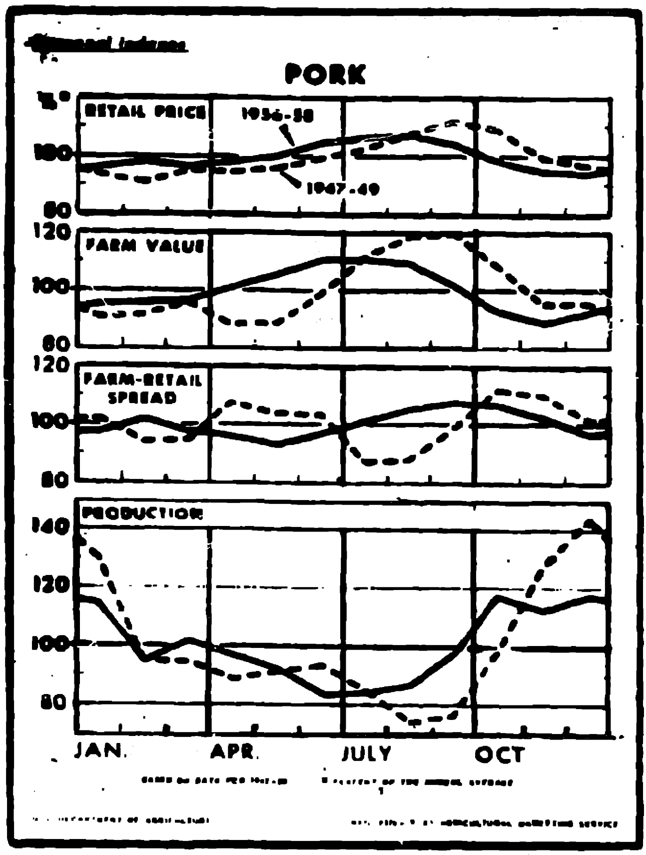


Figure V.15: Seasonal Components of Marketing Margins

16. Per Capita Consumption

An examination of consumers' response to price of pork indicated there is essentially no adjustment delay (Tomek, 1962; p. 725). Thus, we do not in the hog model distinguish between the equilibrium and the current value of per capita consumption. PCC of pork is a function of many factors (Williams & Stout; pp. 95-104). Only three of these, the season, price of alternative meats, and pork price, change significantly over the course of one cycle. Income, urbanization, occupation, etc. will shift the consumption function over longer periods, but are of no interest to us here.

We have eliminated seasonal trends from our model, but competition from other meats could be an important factor. However, studies indicate the cross elasticity of demand to be sufficiently low that the price of beef, veal, lamb, and chicken need not be considered in specifying pork consumption:

Table V.5: Cross Elasticities of Demand for Pork

	Retail Prices of			
	Beef	Veal	Lamb & Mutton	Chicken
Quantity of Pork demanded	.13	.04	.03	.07

Source: (Brandow)

To infer the relative influence of price on per capita consumption we plot yearly per capita consumption vs. average price during the year (Figure V-16, next page). The resulting scatter diagram has been hand fitted with a line which exhibits a price elasticity of about 0.8. This agrees with the elasticities obtained in other more elaborate studies.

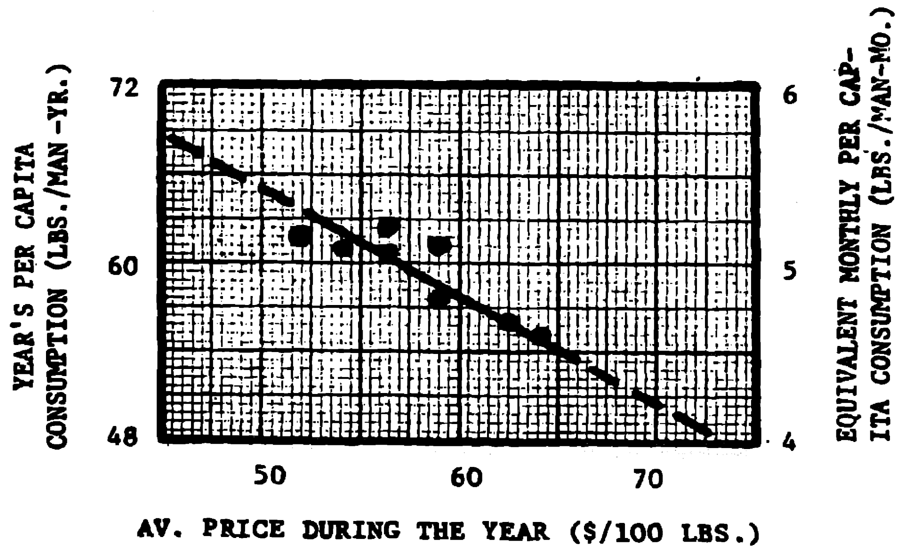


Figure V.16: Per Capita Consumption vs. Average Year's Price

```
PCCP.k

PCCP.K=TABLE(CONTAB,RP.K,40,80,20)

CONTAB=6.4/5/3.7

     CONTAB  - CONSUMPTION TABLE                  (LBS./MAN-MO)
     PRICE   - COMMODITY PRICE                    ($/100 LBS)
     PCCP    - PER CAPITA CONSUMPTION OF PORK     (LBS./MAN-MO)
```

Table V-6: Elasticity of Demand for Pork

Author	Elasticity of Yearly PCC of Pork
Brandow	-.75
Tomek	-.74 & -.78

17. Pork Consumption Rate

Pork consumption rate is the product of per capita consumption and the population of consumers. The United States' population currently is increasing at the rate of 0.79 percent per year. Thus, it is essentially constant over the duration of the four year cycle we are interested in explaining. We assume the population eating out of civilian supplies to be a constant 200 million.

```
CR.KL=(POP)(PCCP.K)+INPUT.K
POP=200E6
     CR     - CONSUMPTION RATE                (LBS/MO)
     POP    - POPULATION OF CONSUMERS         (MEN)
     PCCP   - PER-CAPITA CONSUMPTION PORK     (LBS/MAN-MO)
     INPUT  - EXOGENOUS INPUT                 (DIMENSNLESS)
```

18. Expected Consumption Rate

Since we have eliminated seasonal factors from the model, processors and distributors are left with only population changes and long term consumer preference and income factors upon which to base expectations about future consumption rate. We will assume expected consumption rate is constant.

```
ECR=9.9E8
     ECR      - EXPECTED CONSUMPTION RATE          (LBS/MO)
```

Analysis of the Dynamic Hog Cycle Model

The equations derived in Chapter V together with specifications of the exogenous consumption input and several DYNAMO control cards are listed in Appendix III.

Analysis of the hog model is conducted as with the general model in Chapter IV. When an exogenous consumption factor of twenty percent is added to consumption rate, a typical production cycle is induced. Its period is forty-four months (Figure V.17); its phase relations and magnitudes are also similar to those of the actual system (Figures V.1 & 2). The Dynamic Cobweb Model does include sufficient relationships to explain the production cycle of a particular commodity.

Test of the Dynamic Model for Cattle and Chicken Cycles

Substantial effort was required to determine which values of the Dynamic Model parameters would best represent the hog system. Adapting the general model so precisely to a particular commodity is justified only where it is important to determine rather closely the costs and quantities which would be involved in the behavior of the system over the course of its cycle. However, much of a commodity's behavior can be explained with simpler changes in the Dynamic Cobweb Model. To illustrate, I have selected two commodities, each an extreme example of long-term cyclical behavior. Cattle exhibit a cycle of fifteen years, chickens a cycle of thirty-one months.

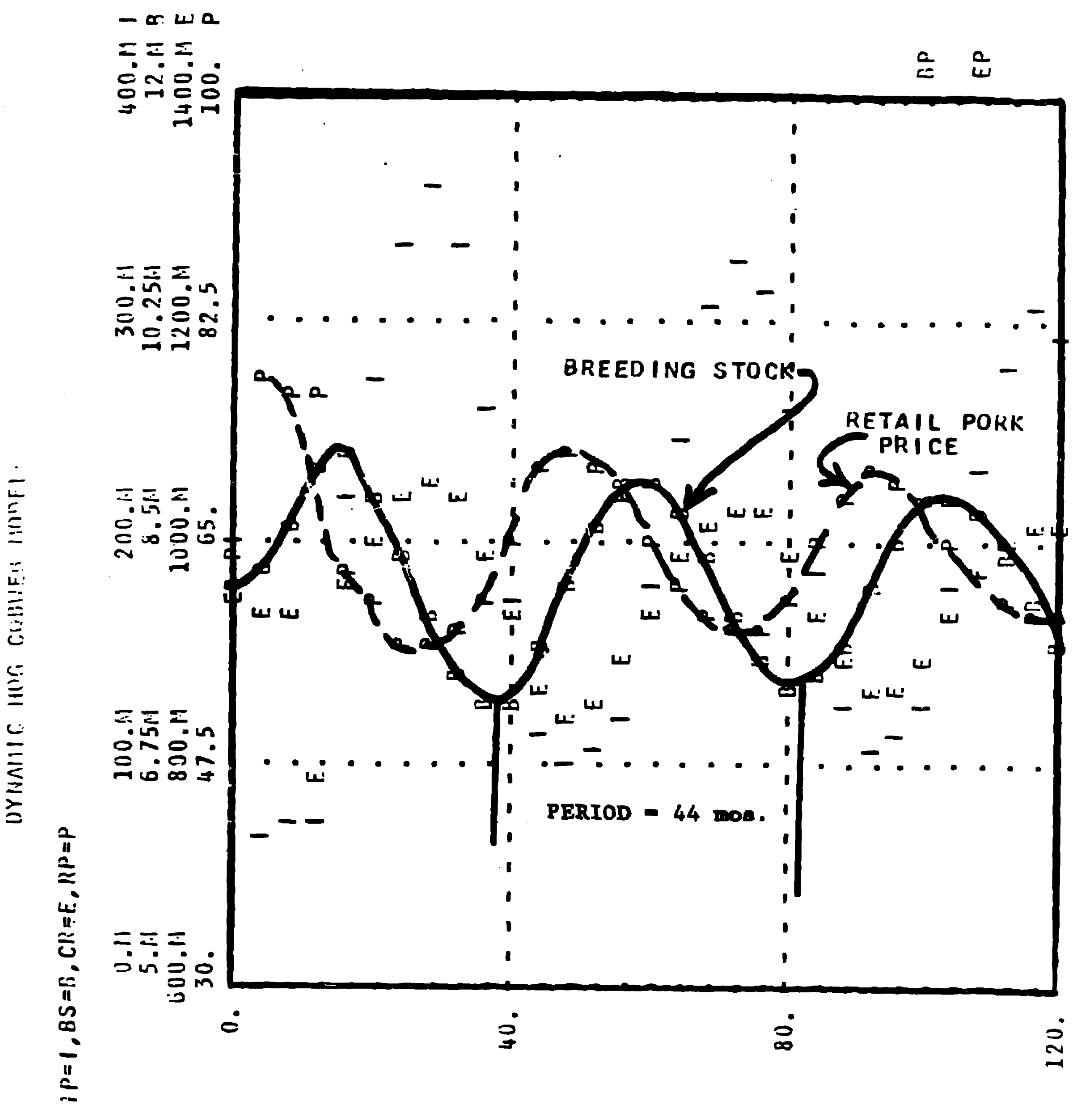
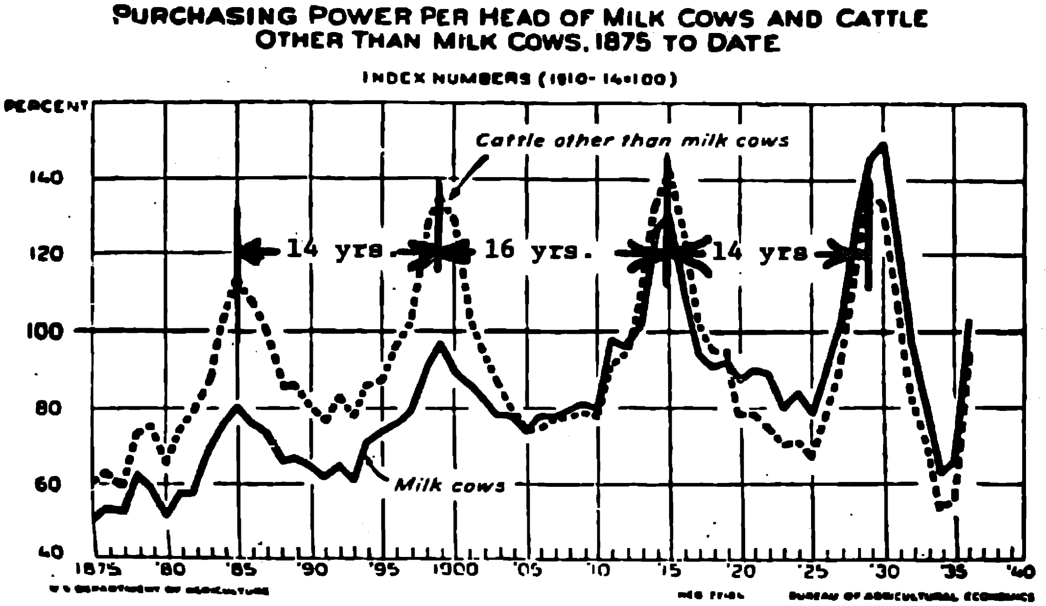


Figure V.17: Behavior of the Dynamic Hog Cycle Model

Using relevant tables from Livestock and Meat Statistics, it was possible by inspection to select initial values, and table functions representative of the cattle system. Empirical literature provided information on the biological delays involved (Maki). The parameter values selected for the general model are listed in Appendix IV. The statistical tables on cattle are included in Appendix V, and the total model specification is provided in Appendix VI. When simulated, this Dynamic Cattle Cycle Model exhibits the fifteen year periodicity of the actual system (Figure V.18).

To represent the production of chickens, even fewer changes were made in the Dynamic Cobweb Model. Only the biological and psychological constants were changed. Capacity transfer delay was set to six months, the time elapsing between the shipment of primary setting eggs to the hatchery and delivery of the first broiler eggs (Table V.7). The production delay time required to raise broilers from eggs, was set equal to three months (Table V.7). The psychological production delays, expected price adjustment delay, and capacity transfer initiation delay, were made lower than those in the hog system to represent the smaller risk associated with investment in chickens. Consumption rate adjustment delay was reduced to the one month found appropriate for meat (Ch. V.16). This model had a periodicity of thirty months (Figure V.19), one month less than that observed in the actual system (Figure V.20). In this last case, of course, the magnitudes of parameters during the cycle bear little resemblance to those in the actual system.

Time constraints have precluded the representation of any additional commodity systems in this phase of the study. It is hypothesized, however,



Source: (Ezekiel; p. 270)

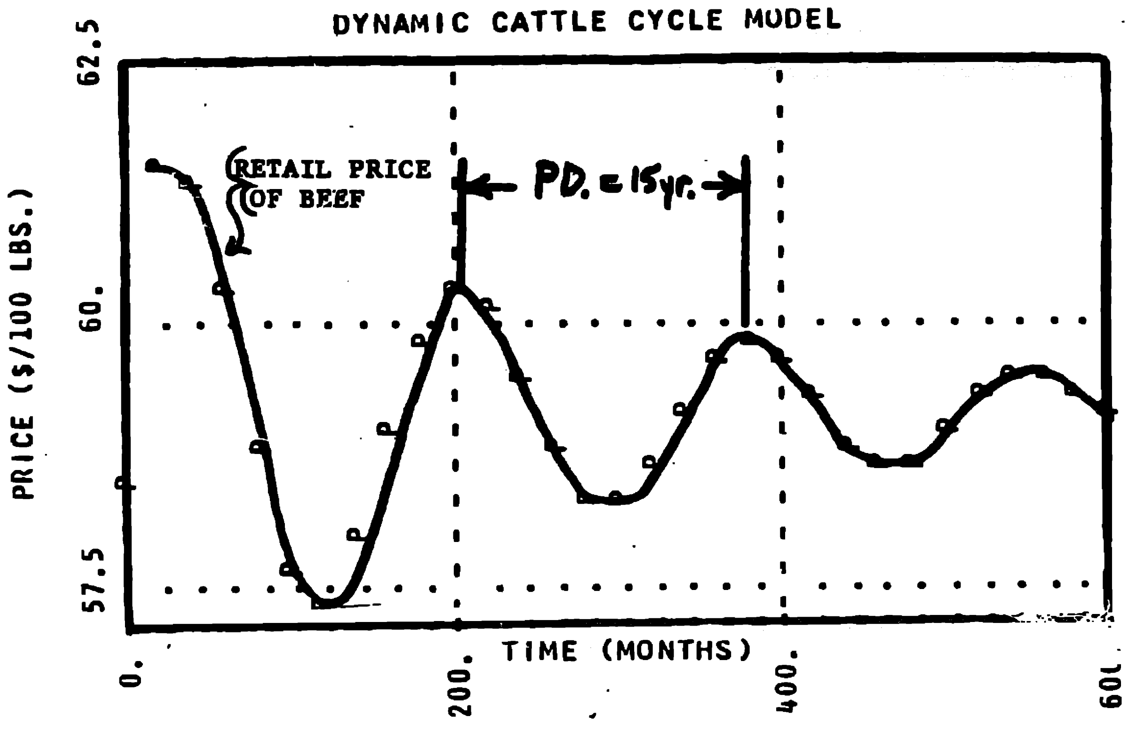


Figure V.18 : Actual and Simulated Cattle Cycle

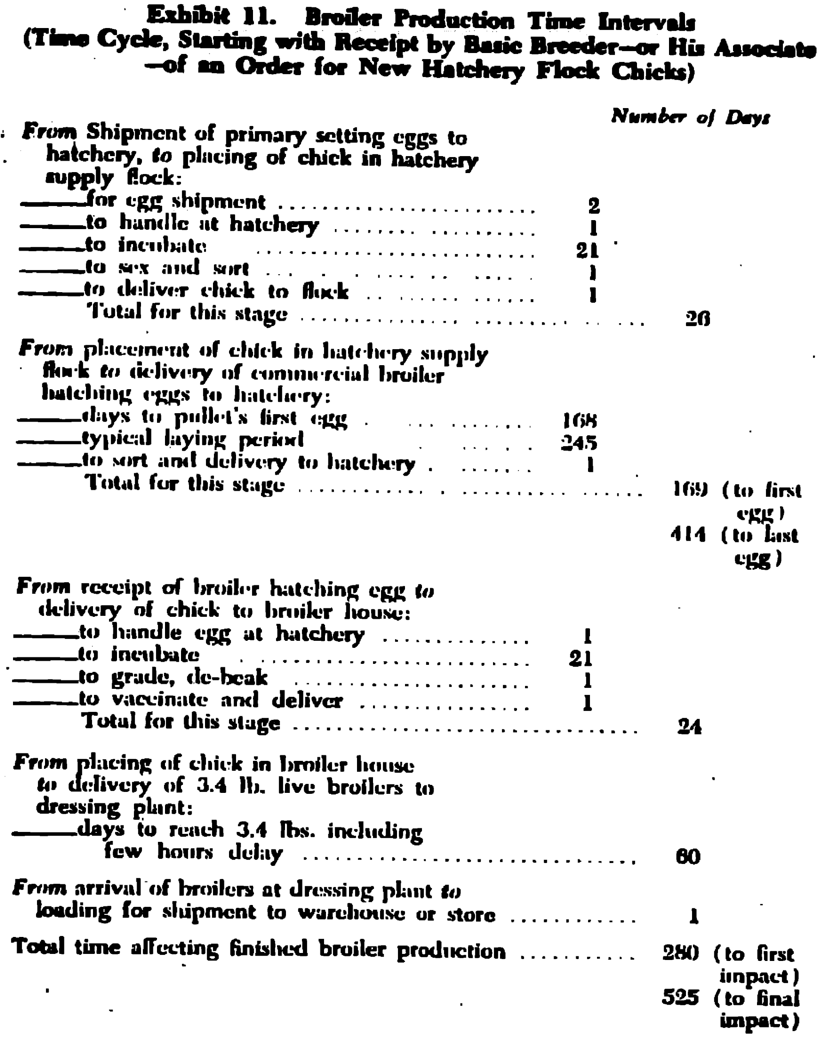


Exhibit 11. Broiler Production Time Intervals
(Time Cycle, Starting with Receipt by Basic Breeder—or His Associate —of an Order for New Hatchery Flock Chicks)

		Number of Days
From Shipment of primary setting eggs to hatchery, *to* placing of chick in hatchery supply flock:		
——for egg shipment	2	
——to handle at hatchery	1	
——to incubate	21	
——to sex and sort	1	
——to deliver chick to flock	1	
Total for this stage		26
From placement of chick in hatchery supply flock *to* delivery of commercial broiler hatching eggs to hatchery:		
——days to pullet's first egg	168	
——typical laying period	245	
——to sort and delivery to hatchery	1	
Total for this stage		169 (to first egg) 414 (to last egg)
From receipt of broiler hatching egg *to* delivery of chick to broiler house:		
——to handle egg at hatchery	1	
——to incubate	21	
——to grade, de-beak	1	
——to vaccinate and deliver	1	
Total for this stage		24
From placing of chick in broiler house *to* delivery of 3.4 lb. live broilers to dressing plant:		
——days to reach 3.4 lbs. including few hours delay		60
From arrival of broilers at dressing plant *to* loading for shipment to warehouse or store		1
Total time affecting finished broiler production		280 (to first impact) 525 (to final impact)

Source: (Tobin & Arthur; p.48)

Table V.7: Biological Delays in the Production of Chickens

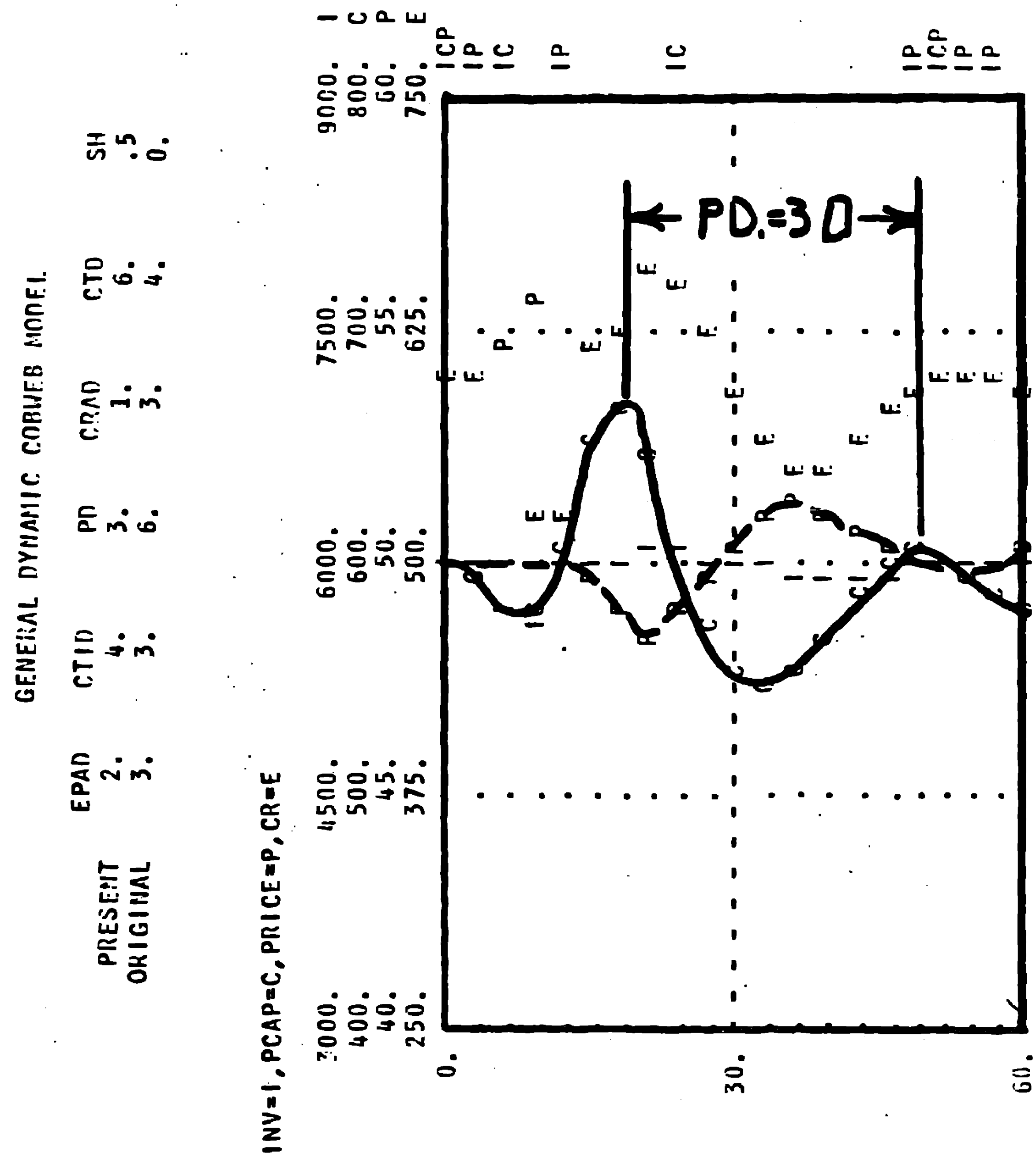
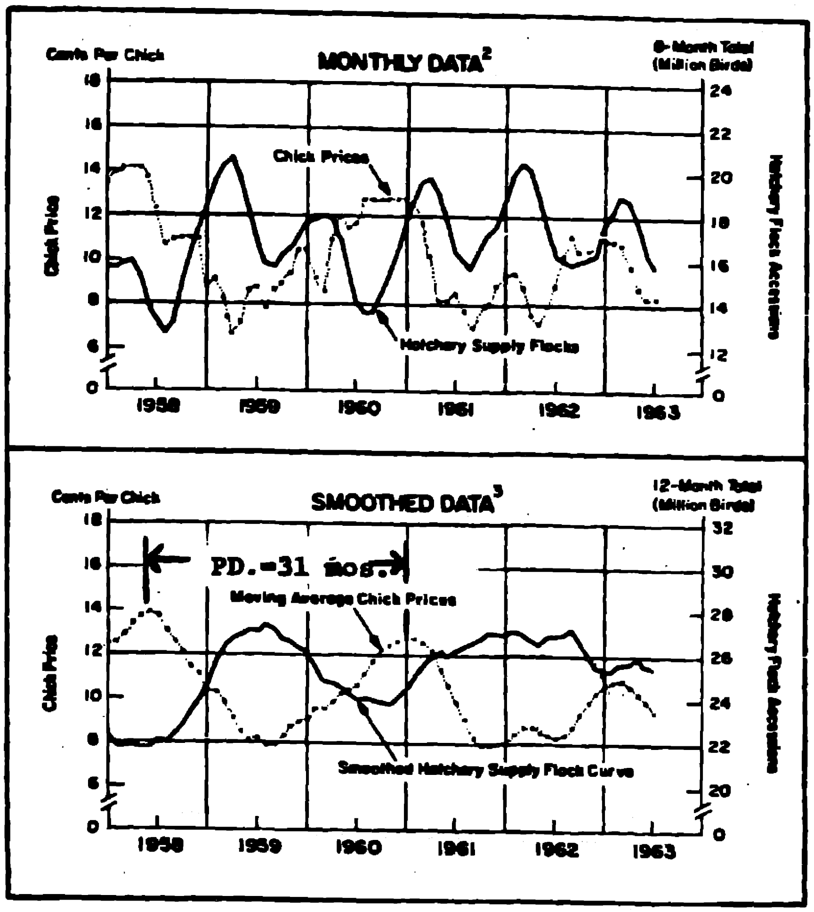


Figure V.19: Dynamic Cobweb Model with Delays from the Chicken System

Exhibit 12. Broiler Hatchery Supply Flocks (Estimated Number of Layers in Laying Houses) and Broiler Chick Prices, Georgia, 1958–1963[1]



[1] Hatchery supply flock estimates are based on data from *Turkeys and Chickens Tested*, monthly bulletin, Statistical Reporting Service, U.S. Department of Agriculture. Monthly data for broiler chick prices are from *Agricultural Prices*, Statistical Reporting Service, U.S. Department of Agriculture.

Source: (Tobin & Arthur; p. 52)

Figure V.20: Measures of the Chicken Cycle that the behavior of any commodity system exhibiting regular long-term cycles, whether in the production of animal, vegetable, or mineral products, can be explained with the Dynamic Cobweb Model. For the moment, we will simply assume that the Dynamic Model is a better general representation of commodity cycles than any other model available. Upon that basis, we turn in Chapter VI to analyze the determinants of its stability.

CHAPTER VI

SOME DETERMINANTS OF STABILITY IN THE DYNAMIC COBWEB MODEL

I have suggested above that a significant decrease in the magnitude of commodity fluctuations can only be accomplished by increasing the inherent stability of the commodity system. Any stabilization scheme must work by altering the structural relationships among production, consumption and price decisions. It is important, therefore, to understand the relation of a system's structure to its stability. The following illustrate, but by no means exhaust, the analyses which should be conducted as a prelude to the design of effective stabilization procedures. In this chapter we briefly examine the effects of changes in the equilibrium capacity and consumption functions, in the consumption and production delays, and in the level of desired coverage.

The Reference System

In analyzing the Dynamic Model we are not interested in the absolute stability of specific model systems, for the precise damping factor resulting from any change is relevant only to that particular structure and set of parameter values. We are interested instead in the relative influence of different changes. Does decreasing the production delay make the system more or less stable? Will a given change in the production or the capacity utilization factor be more effective in decreasing price fluctuations? Answers to these and many other similar questions will generally be applicable to any system represented by the general structure, whatever the values of its parameters.

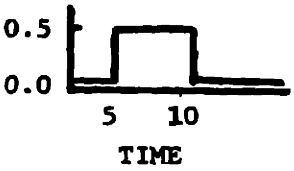
This approach requires a reference system whose stability may be compared with systems in which specified changes have been made. For purposes of comparison we take the Dynamic Cobweb Model exactly as derived in Chapter IV and listed in Appendix I.

We determined in Chapter IV that either a pulse or a noise input could be used to determine the inherent period and the phase relations of a commodity's production cycle. The use of a noise input has one disadvantage, however. It obscures the damping factor of the system. Since the objective of this chapter is to determine the relative stability of alternative system structures, it is important to measure damping. We will, therefore, employ a pulse input in most of the simulations. With the exogenous influence thus confined to one point at the beginning of the simulation, it will be unnecessary to extend each computer run until the system reattains equilibrium. We may simply determine the system's damping factor from the first few cycles.

The exogenous influence is introduced through the consumption rate as in Chapter IV:

CR.KL=(PCCP.K)(POP)(1+INPUT.K)

INPUT.K :



CR = CONSUMPTION RATE
PCCR = PER CAPITA CONSUMPTION REQUIREMENTS
POP = POPULATION
INPUT = EXOGENOUS INPUT TO CONSUMPTION

Price, production rate, and initiation rate were monitored in the simulations of Chapter IV to permit comparison with actual commodity data on those parameters. In general, however, inventory, price, consumption

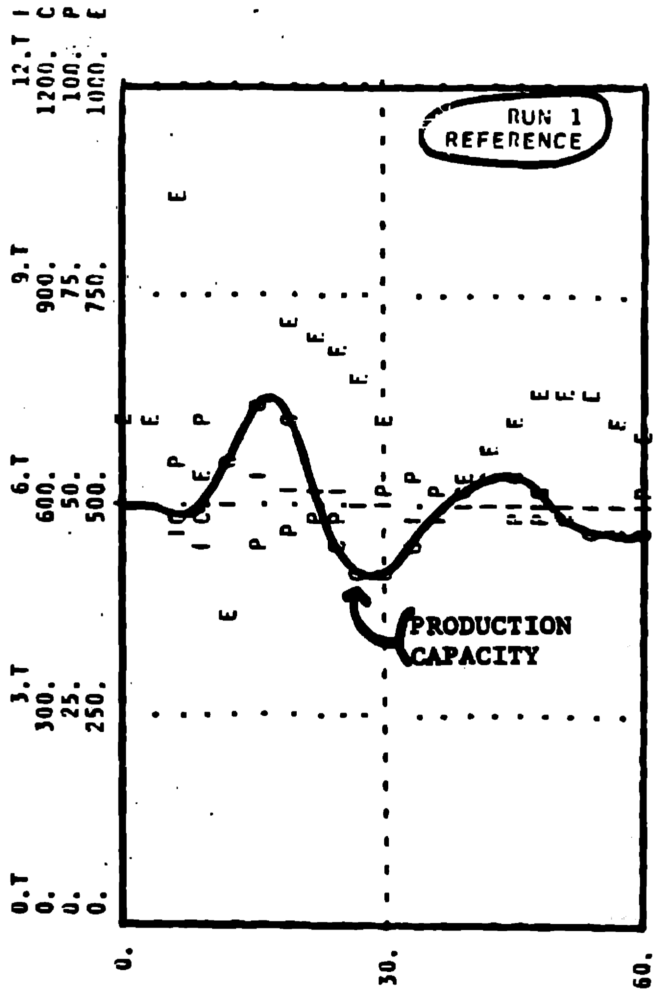


Figure VI.1: RUN 1-Reference Simulation, the Dynamic Cobweb Model with an Exogenous Pulse Input to Consumption Rate

rate, and production capacity provide a better description of commodity system behavior. We will thus monitor each of those four parameters in our simulations. We need measure only one of the four to determine the damping factor of the system; production capacity will be used in each of the following runs.

When the input defined above is applied to the reference model, the now familiar production cycle is induced. Its period, again, is twenty-seven months, and its damping factor is approximately 0.6 (Figure VI.1). In the

Table VI.1: Parameter Changes for the Analyses of the Dynamic Cobweb Model

	RUN	PARAMETER VALUES								
	1	SH								
PRESENT		.5								
ORIGINAL		0.								
	2	SH	CATAB	. . .	. . .	. . .	. . .	. . .		
PRESENT		.5	0.	10.	50.	1150.	1500.	1600.		
ORIGINAL		0.	0.	40.	200.	1000.	1200.	1280.		
	3	SH	COTAB	. . .	. . .	. . .	. . .	. . .		
PRESENT		.5	5.	4.75	4.25	1.75	1.25	1.		
ORIGINAL		0.	7.	6.5	5.	1.	.3	0.		
	4	SH	PD	CTD						
PRESENT		.5	4.	3.						
ORIGINAL		0.	6.	4.						
	5	SH	CRAD							
PRESENT		.5	6.							
ORIGINAL		0.	3.							
	6	SH	CRAD							
PRESENT		.5	100.							
ORIGINAL		0.	3.							
	7	SH	CRAD	CUTAB	. . .	. . .	. . .	. . .	. . .	. . .
PRESENT		.5	100.	.3	.6	.8	1.	1.2	1.4	1.7
ORIGINAL		0.	3.	1.	1.	1.	1.	1.	1.	1.
	8	SH	CRAD	PUTAB	. . .	. . .	. . .	. . .	. . .	. . .
PRESENT		.5	100.	.3	.6	.8	1.	1.2	1.4	1.7
ORIGINAL		0.	3.	1.	1.	1.	1.	1.	1.	1.
	9	SH	CRAD	PUTAB	. . .	. . .	. . .	. . .	. . .	. . .
PRESENT		.5	100.	.3	.6	.8	1.	1.	1.	1.
ORIGINAL		0.	3.	1.	1.	1.	1.	1.	1.	1.
	10	SH	NM	LENGTH	SI					
PRESENT		0.	.3	120.	4.					
ORIGINAL		0.	0.	60.	8.					
	11	SH	NM	LENGTH	PIT	SI	DCOV	INVN		
PRESENT		0.	.3	90.	30.	4.	3.	1800.		
ORIGINAL		0.	0.	60.	0.	8.	10.	6000.		

subsequent simulations individual changes were made in this reference model. The original and revised values of all affected parameters are given in Table VI.1. Those parameters not appearing in the table retained their original values throughout the study of stability.

Equilibrium Capacity and Consumption Functions

The Static Cobweb Analyses of Chapter III employ only a system's "supply" and "demand" schedules. We have subsequently shown that production and consumption are in fact determined by the interaction of numerous psychological, physical, and biological factors, which may change independently. There is no unambiguous way of relating a specific change in any of these factors to revisions in the supply or demand schedule. For this reason alone the Static Cobweb Theorem is useless in any quantitative analysis of commodity behavior. Its conclusions are qualitatively correct, however. Any factor which changes to increase the long-term response of the production sector to a change in price, does destabilize the system. Any factor which changes to decrease the short-term response of consumption to price changes has a similar effect.

Runs 2 and 3 illustrate the effect of changes in the desired capacity and the consumption tables, the two Dynamic Model elements which most closely approximate the supply and demand functions of the Static Theorem. In Run 2, price-elasticity of desired capacity was increased thirty-seven percent over the relevant range of expected price. The new system is less stable than the reference. The damping factor is decreased to about 0.2.

Decreasing the elasticity of equilibrium consumption a similar amount, thirty-seven percent, has a much greater influence upon the stability of the system (Run 3). The damping factor for the system with less elastic consumption is about zero. Oscillations induced by the pulse input are essentially sustained.

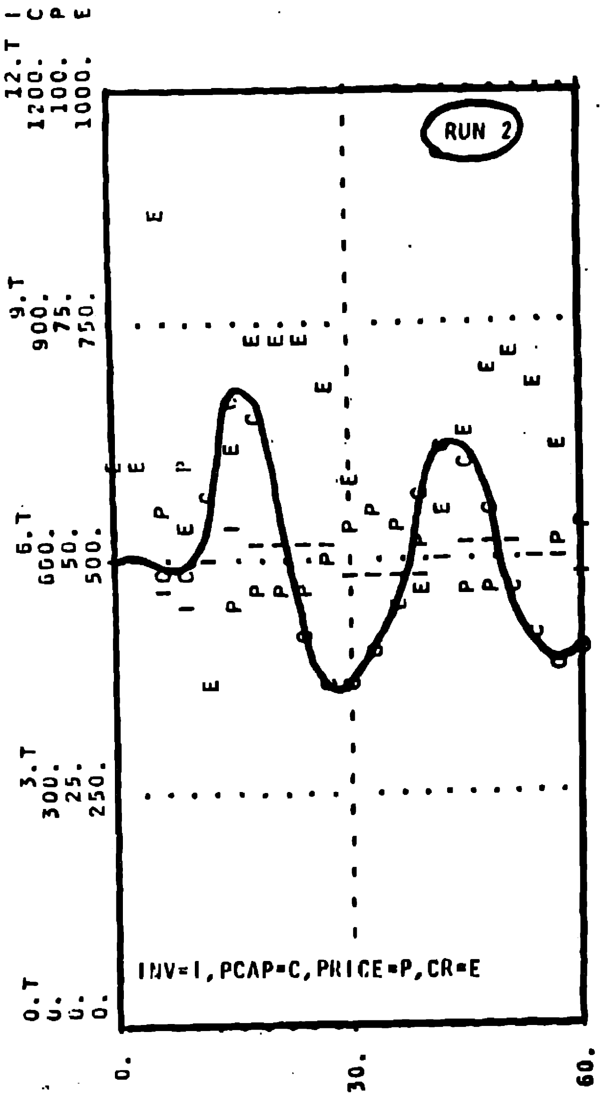


Figure VI.2: RUN 2-Capacity Table Made More Price-Elastic

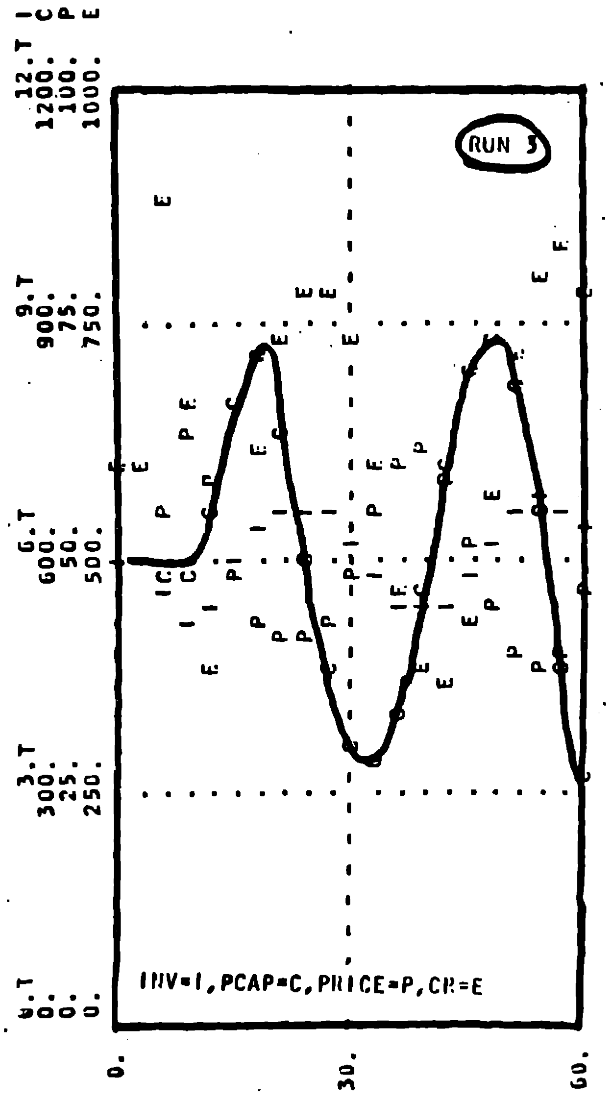


Figure VI.3: RUN 3-Consumption Table Made Less Price-Elastic

The price-response of production and consumption may also be altered by a change in one or more of the delay constants. In Run 4, the production and capacity transfer delays were decreased a total of three months. The resulting system damping factor was .3. The system still exhibits convergent oscillations, but it is substantially less stable than the reference system (Figure VI.4). Again, a similar change in the consumption loop has a greater impact on stability. In Run 5, consumption rate adjustment delay is increased three months. In the consumption sector the three month change produces a system which is explosively unstable. The damping factor is -0.5, and the standard pulse input thus produces divergent oscillations. As a general rule, a change in the delays or the table functions of the consumer sector will have a greater influence on system stability than a change of the same magnitude (but opposite direction) made in the production loop. Since total delay around the consumption loop is much less than the total of all delays in production, a given change is proportionately more important in the consumption relationships.

Utilization Factors

Ezekiel noted one shortcoming of the Static Cobweb Theorem:

> Even for the commodities which approximately fulfill the assumptions, however, the theory must be limited. In many commodities farmers can do little to increase their future production, once they have made their initial commitment in acres seeded or in animals bred. But altho they cannot increase, they can reduce at any time until the product is finally marketed, by plowing up portions of the crop or letting it go unharvested, by slaughtering breeding stock, or by slaughtering pigs young instead of fattening them. There is thus in practice some elasticity of response left, on the downward side at least. (Ezekiel; p. 272).

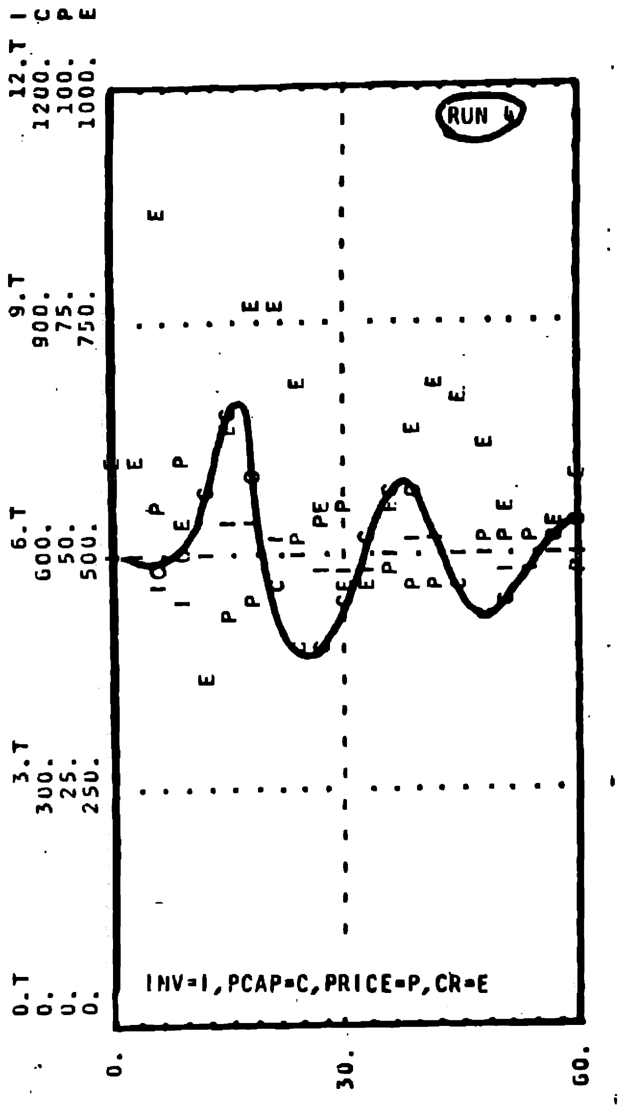


Figure VI.4: RUN 4-Production and Capacity Transfer Delays Decreased

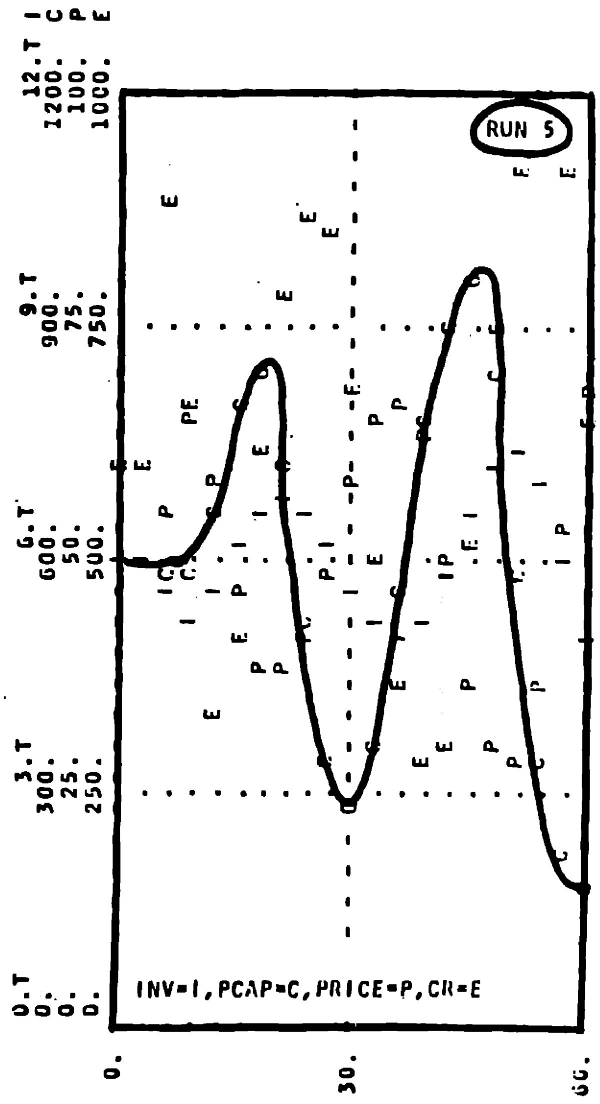


Figure VI.5: RUN 5-Consumption Rate Adjustment Delay Increased

[redacted]

The Static Model assumes that production capacity is fully utilized. It is thus impossible to analyze the implications of this increased flexibility. This omission in the Static Theorem is a serious limitation, since variations in the utilization of productive capacity and in the stocks of commodity already produced have been very common means of stabilizing commodity systems. Capacity often has been idled and commodity stocks destroyed or diverted to noncompetitive uses after prices became depressed.

Although, as Ezekiel notes, less use has been made of changes in utilization during high prices, this is a promising policy.

> Increasing the short- and medium-term production response to prices by adjusting the level of applications of fertilizers and pesticides provides another way of breaking the long-term cycle, less efficient than the (counter-cyclical planting policy), but much less demanding in terms of forecasting abilities. (Goreux; p.i)

> The introduction of a flexible mining policy, one that would permit the production of higher grade ore during periods of relatively high price and the mining of lower grade ore during periods of relatively low prices, succeeded (in simulations of copper production) in reducing price fluctuations to some extent. (Ballmer; p. 4)

One may distinguish between use made of the available productive capacity in initiating new commodity and use of producers' stocks of essentially completed commodity. The difference is that between not planting a field and not harvesting its mature crop. Either of these general policies may be studied within the context of the Dynamic Model.

Because the effects of utilization policies are much smaller than those observed above, Run 1-5, it is useful to define as a reference a system which is extremely unstable. In Run 6, the consumption rate

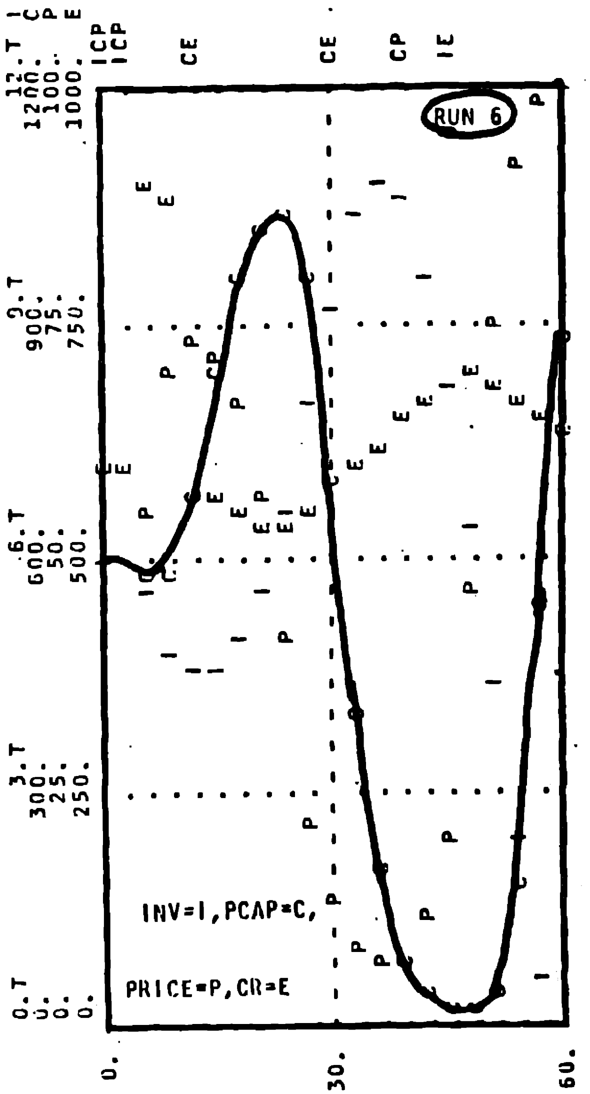


Figure VI.6: RUN 6-Consumption Rate Made Essentially Constant

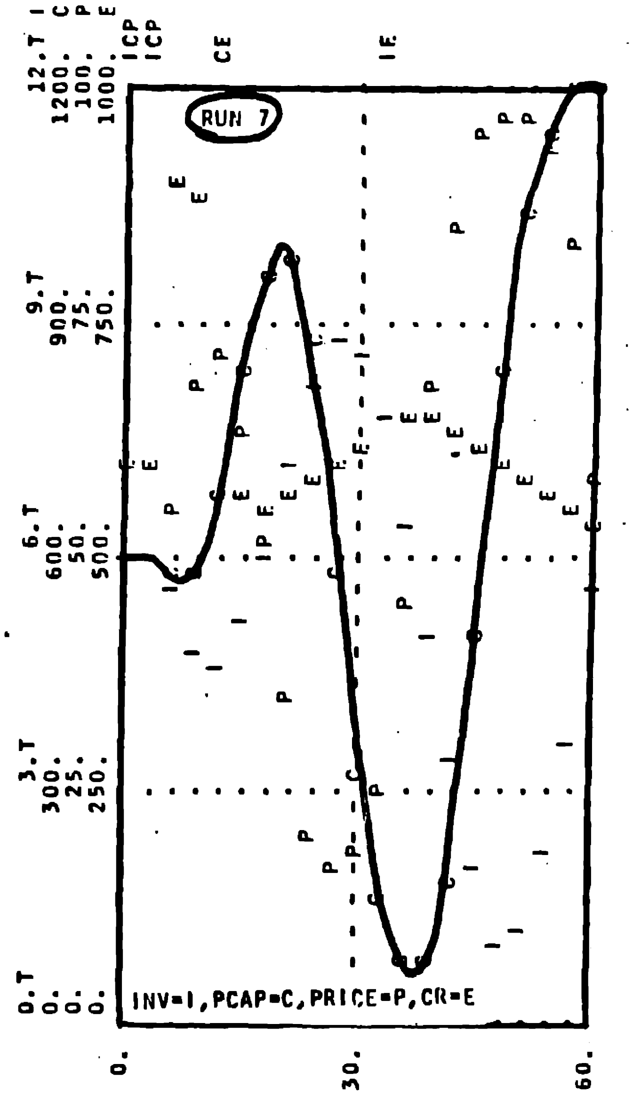


Figure VI.7: RUN 7-Capacity Utilization Factor Made Variable

[redacted]

adjustment delay has been increased to 100 months, consumption rate is essentially constant and any disturbance from equilibrium results in markedly divergent fluctuations. Into this system we introduce three different utilization policies.

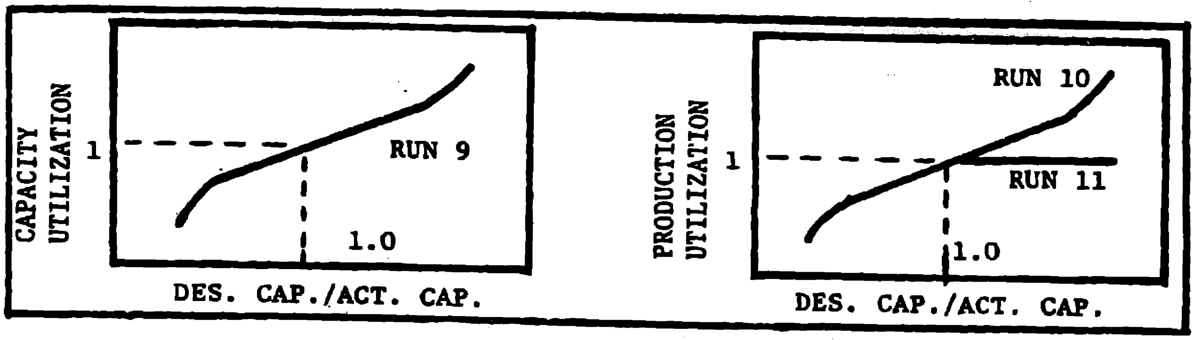


Figure VI.8: Three Alternative, Variable Utilization Policies

Where a policy of variable utilization is applied to production capacity, Run 7, it effects the initiation rate:

```
INR.KL=(PCAP.K)(CUF.K)
```

Its impact on inventory is thus delayed the length of the production delay, but the policy does increase system stability (Figure VI-7). Where the utilization policy effects production (Run 8 & 9):

```
PR.KL=DELAY3(INR.JK,PD)*PUF.K
```

it impacts on inventory directly, and is consequently more effective. (Figure IV.9).

Where production utilization is free to respond both to high and to low prices, it is markedly more effective than a similar capacity utilization policy (Run 8 vs. Run 7). If there is no possibility of making production utilization greater in response to high price, the production policy becomes less effective (Run 9 vs. Run 8). Even with this restriction, however, varying the intensity of production remains a more effective

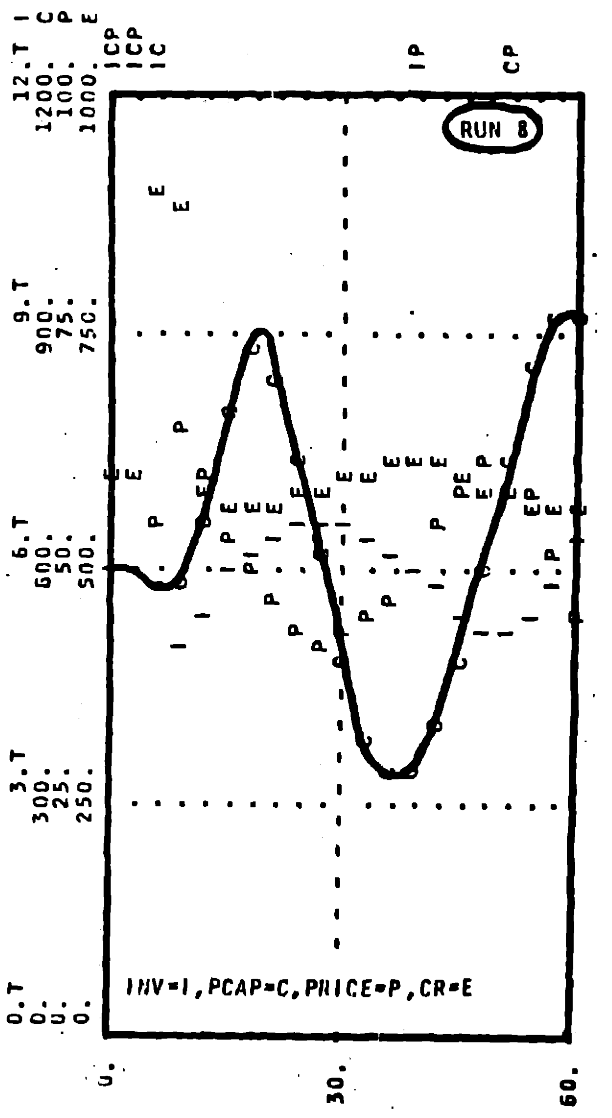


Figure VI.9: RUN 8-Production Utilization Factor Fully Effective

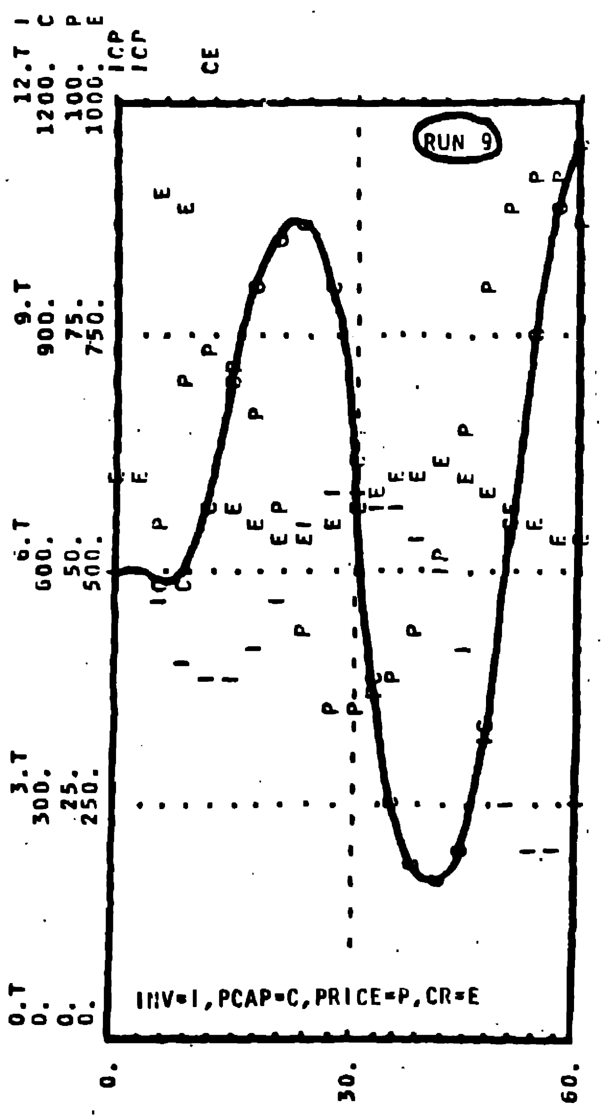


Figure VI.10:RUN 9-Production Utilization Factor Set to Permit Dumping Only means of damping fluctuations than changing the percent of capacity employed (Run 9 vs. Run 7).

Desired Coverage

It has been shown in the analyses above that changes in either the production or the consumption sectors may alter the stability of the commodity system. Here we examine the influence of an important decision by those who process and distribute the commodity, the choice of desired inventory coverage. Runs 10 and 11 differ only in the initial values of inventory and desired coverage. In the latter simulation, desired coverage and initial value of inventory were both reduced to thirty percent of their original value. Both systems are initially in equilibrium; both are subjected to the same sequence of noise in their consumption rates. Lowering desired coverage by seventy percent increased the magnitude of the fluctuations in capacity by about 250 percent.

Structural Changes

The simulations above analyze only simple changes in the model's parameter values. It should be quite clear, however, that the influence of alternative structures could be studied in a similar fashion. For example, the relation of current price to expected price is an important element of the system. That relation can be altered by information programs or marketing board arrangements. It is important to understand how different forecasting rules influence system stability.

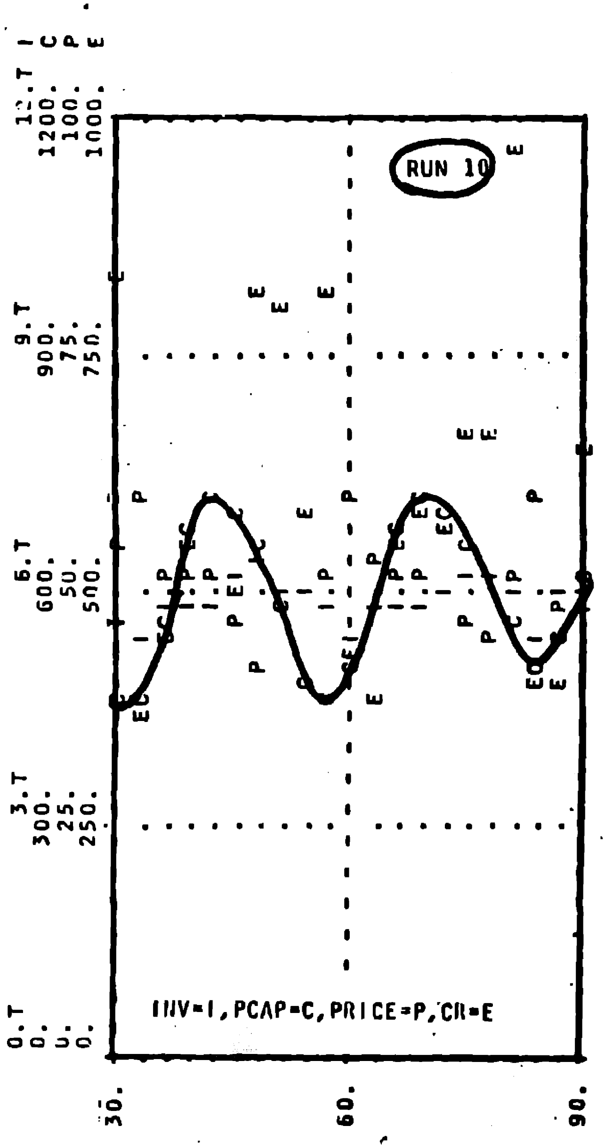


Figure VI.11: RUN 10-Consumption Noise with Normal Desired Coverage

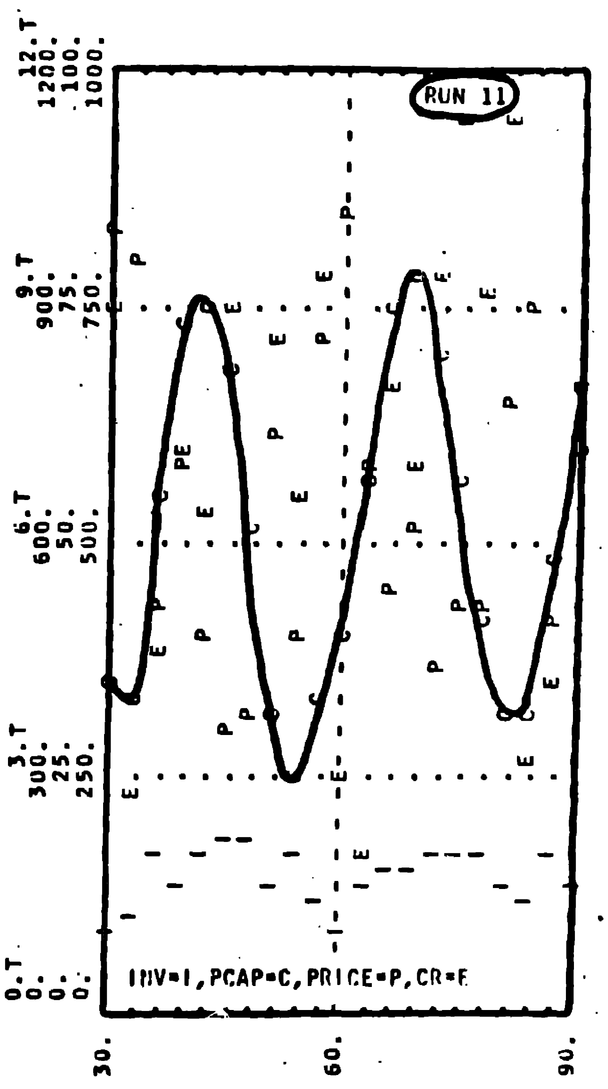


Figure VI.12: RUN 11-Consumption Noise with Decreased Desired Coverage

Many of the traditional stabilization schemes involve structural changes in the Dynamic Model. Buffer stocks, for example, act by changing the relative coverage-price relationship. Producer subsidies change desired capacity's dependence on expected price. Import restrictions will alter per-capita consumption. All of these structural changes could be analyzed through simulations of a simply-revised Dynamic Model. These are beyond the scope of this thesis. In the concluding chapter, however, I will summarize the thesis research and point to its more fruitful extensions.

CHAPTER VII

CONCLUSION

The study reported here was undertaken to develop and validate a more powerful tool for the design of commodity stabilization policies. The focus of the initial effort has been on methodology rather than on specific recommendations for commodity agreements. In concluding this phase of the effort it is appropriate to summarize the implications of the study for the conduct of commodity research and to indicate the extensions of this work which will be most useful in the formulation of specific approaches to commodity stabilization.

Implications of the Study

In the process of developing a general theory of commodity production cycles, I have substantiated several principles of commodity research relevant to the areas of data collection, model formulation, and analysis.

Collecting Data-

When an analyst is unable to explain the behavior of a system, he may either:

- admit ignorance of the system's structure, i.e. of the important interactions among the system's elements.
- claim that more data is required on the precise value of certain system parameters.

The latter excuse is most often found in the literature on commodity cycles. This thesis demonstrates that readily available statistical data in combination with a structure derived from the experience of those involved in the system are sufficient to explain the phase relationships, the periodicity, and the stability of specific commodity cycles.

For administrators a model is sufficiently accurate if it leads them to select the correct policy alternative. Experience with many Industrial Dynamics studies suggests the ranking of policy alternatives generally is sensitive to only a few assumptions in each model. Though attention should be concentrated on those few factors, it appears that commodity research focuses primarily on parameters which are already sufficiently understood. An example is current research on supply and demand.

The price-elasticities of supply and demand have received more attention by economists than any other pair of parameters. However, the precise values of these elasticities are relatively unimportant in choosing among stabilization policies. For example, the relative effectiveness of the capacity and the production utilization policies studied in Chapter VI would not be altered by a change in the model's elasticities. On the other hand, the exact nature of the desired coverage decision may be an important factor in determining the relative effectiveness of alternative policies. There has been essentially no empirical research into this factor.

The success of the simple inference methodologies employed in Chapter V suggests that sophisticated econometric techniques are not absolutely essential in understanding a system. In fact, the nature of feedback interactions violate many of the assumptions underlying traditional statistical inference techniques.[1]

It is important not to waste scarce analytical resources on unnecessary or invalid analyses. The formulation and analysis of quantitative models should precede intensive data collection in the study of commodity problems.

---

[1] Weymar (pp. 29-31) briefly describes the requirements which one aspect of feedback interaction places upon the form of regression analysis.

Formulating the Model-

Commodity systems are a subject of concern primarily because they are not in equilibrium. Commodity analysts are thus less interested in the equilibrium value of commodity parameters than in the path those parameters take when the system is disturbed from equilibrium. The equilibrium point becomes in many instances less important than some measure of the system stability, for example the damping factor defined in Chapter III. Research into the correlates of commodity systems' stability requires a dynamic model.

One effective stabilization policy studied in Chapter VI, varying the utilization of production, depended upon the introduction of a non-linear relation between production capacity and production rate. To study the effects of similar control approaches, commodity models must thus be able to incorporate non-linear relationships.

The Static Cobweb Model reviewed in Chapter III does not permit quantitative representation of alternative policies. It is important to employ models complex enough to represent each parameter which is subject to change through policy decisions.

Complex, dynamic, non-linear models will be required for the evaluation of alternative commodity policies.

Conducting the Analysis-

The analysis of Nerlove's Static Model in Chapter III illustrates the effort and expertise required to analyze mathematically even comparatively simple, linear commodity models. Few policy makers could follow the logic of the analysis or repeat it for a slightly different set of assumptions. In contrast, the twelve analyses of the Dynamic Cobweb Model in Chapter VI could have been conceived and conducted by anyone familiar with commodity systems after only an hour's instruction in DYNAMO. The analyses of this more complex model required less than an hour's effort and only five dollars of computer time.

If the best available model can be analyzed mathematically, that approach does yield more precise and general solutions than those available from simulation. However, it is a mistake to limit the comprehensiveness of the model in order that it may be analyzed mathematically. The costs inherent in such constraints are illustrated by the differences between the Static Cobweb Model as it is used by Samuelson to explain hog cycles (pp. 484-486), and the hog model developed in Chapter V. The static model predicts a two year hog cycle and provides no opportunity to determine quantitatively the effects of alternative control policies. By simply eliminating those assumptions imposed for analytical convenience, the simulated model gains dynamic validity and the power to represent any stabilization policies of interest.

This study makes concrete the general statements of Cohen and Cyert.

> Computer models may be the most efficient approach when the model portrays a dynamic process and numerical answers in the form of time series are desired.
>
> The usual procedure is to construct a model which specifies the behavior of the components, and then to analyze the model to determine whether or not the behavior of the model corresponds with the observed behavior of the total system. When this model is sufficiently complex, either because of the nature of the underlying functions or the number of variables contained in it or both, computer simulation may be the most convenient technique for manipulating the model (Cohen & Cyert; p. 118)

The necessary computers and efficient software such as DYNAMO are readily available. Simulation should be made the dominant mode of analysis in commodity research.

Extensions of the Study

The Dynamic Cobweb Model alone constitutes a powerful tool for the study of alternative control policies. However, the full potential of this general approach to commodity problems will be realized only after additional work in four areas.

Analyzing Specific Policies-

In Chapter VI I presented several analyses of the relation between the structure and the stability of a commodity system. I outlined there the approach which could be followed to represent specific policies. The Bauer-Paish buffer fund proposal, buffer stocks, quotas and bilateral agreements can all be studied with simple extensions of the Dynamic Cobweb Model. Of these four, the first is probably most important.

The buffer fund is one approach which can be enacted unilaterally. It does,therefore, eliminate many problems of implementation. However, there is disagreement about its exact effects on the level and the stability of a nation's commodity export income. The implications of one effective national buffer fund on the stability of the entire international system is also uncertain. There is some suggestion, however, that buffering as little as thirty percent of the world's output might significantly stabilize the entire system.[2]

Information on each of these questions could easily be obtained through analyses of the Dynamic Cobweb Model. The study would merely require a Dynamic Model with two production sectors. One, representing the controlled economy, would be modified to include the effects of a Bauer-

---

[2] Schlager found that one company could stabilize the entire copper processing industry through its pricing decisions. I have observed similar results in one other American commodity market.

Paish fund on the determination of price and the formation of producer price expectations. The other, unmodified, would represent production in the remainder of the world.

Extending the Model-

Income stability is not an objective in itself. It is sought as one means of facilitating self-sustained growth among the underdeveloped economies. Policies made in response to commodity fluctuations have implications for total commodity income, for other agricultural activities, and for the industrial and political sectors of the country. It is important to extend the boundaries of the Dynamic Cobweb Model so that stabilization policies may be evaluated within this broader context.

The relative decline in commodity income, described in Chapter II, should certainly be studied in parallel with the problem of instability. Income fluctuation and stagnation are clearly related phenomena. The risk of price fluctuations is a cost borne by all those who carry commodity stocks. Much of the incentive to develop synthetic alternatives for primary materials may come from the wish to avoid that cost. Thus decreased fluctuations should lead to increases in both consumption and production at any given price. It is important to determine whether commodity stabilization would also yield increased income over the long run. Extension of the Dynamic Model to include the influence of fluctuations on equilibrium production and consumption decisions would permit study of this important question.

As analysts identify the feedback structure underlying the performance of other sectors in underdeveloped economies, the resulting models may easily be combined with the Dynamic Cobweb Model. Implicit in the model's initiation and production rates is a given level of employment. Addition of a few appropriate employment factors would thus link the Dynamic Model to another model of personnel movements within the country. The production rate and commodity price determine producers' income; the production capacity change rate determines the amount of investment required by the commodity sector.

The Dynamic Cobweb Model, a relatively simple example, explicitly combines biological, psychological, physical, and economic hypotheses into a single model of commodity cycles. The methodology of Industrial Dynamics and the logic of Dynamo lend themselves well to a modular approach to model building. They provide a common language which enables specialists in many disciplines to cooperate in the formulation of comprehensive models.[3]

An important extension of this work is application of its basic methodology to other sectors of the underdeveloped economy.

Conducting Sensitivity Analyses-

False assumptions can lead to false conclusions whatever the mode of analysis. Where policy recommendations are found to be quite sensitive to the precise form or value of some assumption, it is important to determine the nature of that relationship in the real world. A third extension of this work thus becomes the identification and validation of pivotal assumptions. An example is provided by the desired coverage assumption analyzed in Chapter VI.

In Chapter IV I suggested that a rational decision maker would choose that level of coverage which just equates the marginal stockout

---

[3] Hamilton et. al. extensively discuss Industrial Dynamic's contribution to this aspect of economic systems research (pp. 276-288).

yield with the marginal carrying cost of his inventory. In this thesis I assumed that desired coverage remains constant over the comparatively brief span of one production cycle. Over longer periods, however, the coverage decision may depend upon the magnitude of fluctuations in the commodity system. Whenever there is a decrease in fluctuations, smaller commodity stocks are required to provide a given level of protection against stockouts. As fluctuations decline, the stockout curve should shift to the left (Figure VII.1). Desired coverage should decrease.

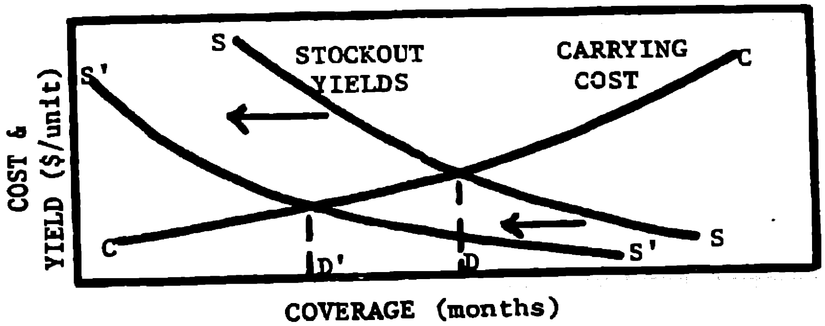


Figure VII.1: Impact of Stockout Yield Decline on Desired Coverage

There is some circumstantial evidence in support of this conclusion. Chapter V mentioned the recent increase in hog system fluctuations (p. 70). This observation is perplexing because several trends in the production of pork should have acted to stabilize that system. Corn price variations have been largely eliminated. Hog production is increasingly concentrated in large production facilities which are most efficient when they maintain a constant production rate. The futures markets and the Department of Agriculture are providing more sources of information on future production and price. At the same time, however, cold storage holdings have decreased from an average of 490 million pounds in 1948 to 208 million pounds in 1966. Since consumption has increased twenty-five percent during the same period, coverage has decreased to only thirty-five percent of its value in 1948. Chapter VI illustrated that a decrease of this magnitude in desired coverage increased the average fluctuations of the Dynamic Model by about 250 percent.

The exact nature of the desired coverage decision is thus very important. If it does respond to decreased fluctuations as suggested above, it would tend to counteract any formal stabilization scheme. A smaller decrease in fluctuations would result from buffer operations than might be suggested by a priori analysis. In effect, a portion of the investment in buffer operations would result only in decreased inventory carrying costs for the producers and distributors.

As commodity models become more comprehensive, the identification and study of critical assumptions will become an increasingly important part of the research.

Understanding Social Choice-

Although a good model of commodity systems will facilitate the design of effective commodity stabilization policies, it may actually impede their implementation. It is naturally easier to obtain a group consensus when the analytical models are so poor that each member believes the proposal will satisfy all of his own goals. As the models become more adequate, the process of social choice must be made more explicit.

Selection from among alternative commodity control policies is a complex process. Simulations of commodity models provide many incommensurate measures of performance. One can not reduce measures of income level and disruption of traditional labor patterns to a single index. Participants in the production, distribution, and consumption of a commodity have many different and conflicting goals. Governments may want to increase their economic influence or their long-term foreign exchange income. Producers may prefer to maximize their short-run profits. Consumers want fast deliveries and low prices. A further complication arises from the empirical fact that complex problems seldom have a dominant solution. There is rarely a policy which yields more of everything good and less of everything bad than any of its competitors.

For problems of this nature, selection from among alternative stabilization policies is inescapably a political process, i.e. one which involves the weighting of conflicting value judgements. Under these circumstances analytical studies can not indicate the "right" answer. They can only quantify the implications of each alternative.

There is little good theory about the procedures of group choice in situations similar to that described above.[4] However, implementation is dependent upon our understanding of that process. To fully utilize the insights developed through this and related studies we must develop an explicit methodology of social choice. That research, in concert with the other extensions described above, appears to offer some hope that we may eventually be able to manage effectively our important commodity systems.

---

4. Arrow presents a comprehensive discussion of the theoretical difficulties implicit in social choice.

APPENDIX I
THE DYNAMIC COBWEB MODEL

A.I-1 Equations

```
*       GENERAL DYNAMIC COBWEB MODEL
NOTE    INITIAL CONDITIONS SET TO EQUILIBRIUM
L       INV.K=INV.J+(DT)(PR.JK-CR.JK)
N       INV=INVN
C       INVN=6000
A       COV.K=INV.K/ECR.K
A       RCOV.K=COV.K/DCOV
C       DCOV=10
A       PRICE.K=TABLE(PTAB,RCOV.K,0,1.998,.333)
T       PTAB=100/94/80/50/20/10/0
L       EP.K=EP.J+(DT)(PRICE.J-EP.J)/EPAD
N       EP=EPN
C       EPN=50
C       EPAD=3
A       DPCAP.K=TABLE(CATAB,EP.K,0,100,20)
T       CATAB=0/40/200/1000/1200/1280
R       CTIR.KL=(DPCAP.K-PCAP.K-CBT.K)/CTID
C       CTID=3
L       CBT.K=CBT.J+(DT)(CTIR.JK-CTCR.JK)
N       CBT=(CTID(DPCAP-PCAP))/(1+CTID)
R       CTCR.KL=DELAY3(CTIR.JK,CTD)
C       CTD=4
L       PCAP.K=PCAP.J+(DT)(CTCR.JK-CDR.JK)
N       PCAP=PCAPN
C       PCAPN=600
R       CDR.KL=PCAP.K/ALPC
C       ALPC=200
R       INR.KL=(PCAP.K)(CUF.K)
A       CUF.K=TABHL(CUTAB,RDAC.K,0,1.998,.333)
A       RDAC.K=DPCAP.K/PCAP.K
T       CUTAB=1/1/1/1/1/1/1
R       PR.KL=DELAY3(INR.JK,PD)*PUF.K
C       PD=6
A       PUF.K=TABLE(PUTAB,RDAC.K,0,1.998,.333)
T       PUTAB=1/1/1/1/1/1/1
A       EPCC.K=TABLE(COTAB,PRICE.K,0,100,20)
T       COTAB=7/6.5/5/1/.3/0
L       PCCR.K=PCCR.J+(DT)(EPCC.J-PCCR.J)/CRAD
N       PCCR=PCCRN
C       PCCRN=3
C       CRAD=3
R       CR.KL=(POP)(PCCR.K)(INPUT.K)
C       POP=200
L       ECR.K=ECR.J+(DT)(CR.JK-ECR.J)/ECAD
N       ECR=ECRN
C       ECRN=600
C       ECAD=100
NOTE    EQUATIONS TO GENERATE EXOGENOUS
NOTE    INPUT TO CONSUMPTION
A       INPUT.K=1+STEP.K+NOISE.K
A       STEP.K=STEP(SH,ST1)+STEP(-SH,ST2)
C       SH=0
C       ST1=5
C       ST2=10
A       NOISE.K=NM*SAMPLE(NORMRN(0,NSD),SI,0)
C       NM=0
C       NSD=.5
C       SI=8
NOTE    CONTROL CARDS
SPEC    DT=.2/LENGTH=60/PRTPER=0/
A       PLTPER.K=STEP(PP,PIT)
C       PP=3
C       PIT=0
PLOT    INV=I(0,12000)/PCAP=C(0,1200)/PRICE=P(0,100)/CR=E(0,1000)
```

A.I-2 Definitions

INV	INVENTORY OF COMMODITY	(UNITS)
INVN	INITIAL VALUE OF INVENTORY	(UNITS)
COV	INVENTORY COVERAGE	(MONTHS)
RCOV	RELATIVE INVENTORY COVERAGE	(DIMENSNLESS)
DCOV	DESIRED INVENTORY COVERAGE	(MONTHS)
PRICE	COMMODITY PRICE	(DOLLARS/UNIT)
PTAB	PRICE TABLE	(DOLLARS/UNIT)
EP	PRICE EXPECTED BY PRODUCERS	(DOLLARS/UNIT)
EPN	INITIAL VALUE OF EX. PRICE	(DOLLARS/UNIT)
EPAD	EX. PRICE ADJUSTMENT DELAY	(MONTHS)
DPCAP	DESIRED PRODUCTION CAPACITY	(UNITS/MONTH)
CATAB	CAPACITY TABLE	(UNITS/MONTH)
PCAP	PRODUCTION CAPACITY	(UNITS/MONTH)
CDR	CAPACTIY DEPRECIATION RATE	(UNITS/MO/MO)
ALPC	AVERAGE LIFE OF PROD. CAP.	(MONTHS)
PCAPN	INITIAL VALUE OF PROD. CAP.	(UNITS/MONTH)
INR	COMMODITY INITIATION RATE	(UNITS/MONTH)
PR	COMMODITY PRODUCTION RATE	(UNITS/MONTH)
PD	PRODUCTION DELAY	(MONTHS)
EPPC	EQUI. PER CAPITA CONSUMPTION	(UNITS/MAN-MO)
COTAB	CONSUMPTION TABLE	(UNITS/MAN-MO)
CR	CONSUMPTION RATE	(UNITS/MONTH)
POP	POPULATION OF CONSUMERS	(MEN)
ECR	EXPECTED CONSUMPTION RATE	(UNITS/MONTH)
ECRN	IN. VALUE OF EX. CON. RATE	(UNITS/MONTH)
ECAD	EX. CON. RATE ADJ. DELAY	(MONTHS)
PCCR	PER CAPITA CONSUMPTION REQS.	(UNITS/MONTH)
PCCRN	INITIAL VALUE OF PCCR	(UNITS/MONTH)
CRAD	CONSUMPTION REQS. ADJ. DELAY	(MONTHS)
CTIR	CAP TRANSFER INITIATION RATE	(UNITS/MO/MO)
CTID	CAP TRANSFER IN. DELAY	(MONTHS)
CBT	CAPACITY BEING TRANSFERRED	(UNITS/MONTH)
CBTN	INITIAL VALUE OF CBT	(UNITS/MONTH)
CTCR	CAP TRANSFER COMPLETION RATE	(UNITS/MO/MO)
CTD	CAPACITY TRANSFER DELAY	(MONTHS)
CUF	CAPACITY UTILIZATION FACTOR	(DIMENSNLESS)
RDAC	RATIO OF DES. TO ACT. CAP.	(DIMENSNLESS)
CUTAB	CAPACITY UTILIZATION TABLE	(DIMENSNLESS)
PUF	PRODUCTION UTIL. FACTOR	(DIMENSNLESS)
PUTAB	PRODUCTION UTILIZATION TABLE	(DIMENSNLESS)
INPUT	EXOGENOUS INPUT TO CONSUMP.	(DIMENSNLESS)

APPENDIX II

HOG STATISTICS

A-II.1 Inventory of Frozen and Cured Pork

Table 220.--Frozen and cured pork: Cold storage holdings, end of month, 48 States, 1940 to date

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds
1940	588,601	650,653	652,733	611,956	592,575	598,522	548,688	417,564	329,214	303,712	408,900	656,169
1941	739,927	791,910	785,387	795,876	798,455	703,893	618,866	485,108	371,362	313,268	350,270	468,538
1942	613,659	616,604	590,416	572,799	550,849	522,173	433,547	336,634	270,287	257,445	291,841	490,476
1943	588,419	627,399	591,597	524,049	519,798	513,784	544,297	497,164	363,615	341,433	383,118	514,247
1944	646,631	792,113	791,867	784,801	769,138	803,357	646,499	478,224	359,023	296,815	318,055	371,393
1945	407,202	366,185	325,503	294,448	305,996	333,019	344,812	285,216	211,004	168,028	235,894	320,571
1946	396,740	426,545	396,753	379,373	382,742	322,433	299,755	168,861	99,859	142,912	209,946	276,232
1947	399,473	399,317	397,794	394,421	364,531	352,814	331,746	264,124	195,896	187,971	304,851	527,159
1948	659,309	700,114	661,399	606,827	580,056	582,496	508,213	359,794	234,909	203,163	310,706	469,153
1949	585,215	611,123	586,429	545,231	466,108	419,590	367,043	283,178	204,678	209,687	297,205	473,741
1950	582,737	573,108	548,640	541,955	492,194	469,361	394,402	303,588	240,544	219,758	326,300	499,408
1951	668,007	641,565	648,384	654,497	616,231	572,372	496,171	401,573	325,959	276,255	381,870	548,604
1952	704,992	793,870	822,006	823,740	727,665	685,033	542,707	407,558	290,931	234,894	319,643	489,152
1953	595,546	606,277	569,204	530,025	459,755	414,227	350,825	265,981	200,597	181,279	266,170	326,812
1954	393,307	413,507	418,283	420,917	384,643	346,765	283,541	228,738	215,057	233,612	340,874	448,645
1955	500,847	532,092	543,703	539,434	477,028	375,741	297,962	218,624	179,182	205,197	306,714	420,816
1956	481,602	517,991	514,124	510,230	457,395	393,538	306,727	203,596	165,514	167,955	248,637	279,763
1957	291,822	333,021	351,518	341,587	322,293	277,336	204,404	147,043	134,035	138,412	163,656	193,931

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds
1958	218,449	227,912	224,322	260,147	242,839	209,936	173,147	149,128	127,033	134,361	184,438	206,414
1959	240,489	315,951	337,120	330,997	365,360	313,141	243,352	193,745	153,447	104,025	223,030	264,210
1960	311,537	342,574	337,921	333,291	306,291	350,683	294,242	220,565	157,012	143,934	153,629	170,226
1961	200,727	234,931	243,667	269,792	263,552	239,730	169,125	136,661	128,235	136,397	193,039	199,974
1962	209,070	235,495	279,707	315,856	338,527	295,051	233,593	131,776	133,530	161,230	211,226	223,520
1963	249,027	275,406	332,583	374,451	356,255	322,511	274,021	219,970	210,408	208,933	250,156	276,685
1964	332,762	382,338	411,228	473,569	468,756	412,933	321,386	229,067	183,965	221,743	274,971	263,634
1965	309,199	318,670	334,761	334,835	292,008	223,514	176,077	134,752	126,295	128,370	141,543	151,883
1966	155,437	183,480	217,053	272,294	268,336	214,134	178,530	139,957	151,037	171,195	205,745	234,233

A-I.2 Live Weight of Hogs Slaughtered

Table 129-130.--Live weight of livestock slaughtered: Estimated average of slaughter under Federal inspection, 1940 to date 1/

HOGS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
1940 ...	233.0	232.6	231.6	230.6	233.1	241.3	249.5	240.1	231.8	224.9	224.7	227.6	232.5
1941....	232.9	237.7	238.3	237.3	239.3	247.6	263.4	261.1	244.9	234.2	233.3	239.2	241.0
1942 ...	239.8	237.0	232.5	234.9	240.4	251.5	265.2	265.7	250.3	240.6	244.6	248.7	245.4
1943 ...	252.1	252.2	252.7	254.0	256.4	260.4	273.9	276.7	262.3	242.7	238.0	244.4	254.5
1944 ...	249.3	246.8	242.5	240.3	238.7	244.8	251.8	255.1	248.0	238.1	238.3	240.1	244.3
1945 ...	244.1	246.3	251.1	257.1	264.5	275.6	297.3	304.2	295.3	276.6	262.7	254.6	264.6
1946 ...	258.4	260.5	248.6	247.6	244.3	263.2	299.5	262.8	264.1	246.2	242.4	246.7	254.7
1947 ...	254.6	251.9	253.3	254.4	260.1	273.3	288.0	283.7	247.3	231.9	234.1	242.2	253.9
1948 ...	253.6	254.9	249.9	244.6	255.3	273.2	281.3	270.8	242.9	233.6	241.4	249.8	252.9
1949 ...	255.2	249.7	245.8	241.5	249.4	265.6	281.8	261.6	234.2	227.6	236.2	243.1	247.6
1950 ...	245.7	238.7	234.3	238.0	245.1	264.1	277.7	259.3	232.6	229.7	237.4	245.2	244.4
1951 ...	249.9	245.1	240.2	241.6	244.4	261.0	275.9	261.7	236.1	230.6	235.6	241.4	245.8
1952 ...	245.7	245.1	239.3	235.6	242.1	255.0	264.7	254.0	236.0	229.2	236.4	241.0	242.6
1953 ...	242.9	234.8	231.1	233.4	244.2	261.3	262.6	258.5	224.6	224.8	234.2	240.0	239.4
1954 ...	244.0	236.5	237.6	246.5	260.6	273.5	264.7	238.2	228.0	232.1	239.6	244.5	243.9
1955 ...	246.7	238.9	239.2	244.0	251.9	263.7	256.4	239.2	229.3	228.0	235.2	237.2	240.8
1956 ...	237.8	233.1	230.6	233.5	239.7	249.5	245.1	232.3	225.2	226.6	233.5	236.9	234.8
1957 ...	236.6	233.4	234.2	237.9	244.8	252.9	244.4	229.2	221.4	226.4	235.8	237.9	235.5
1958 ...	236.2	230.2	232.8	238.6	245.9	250.8	244.5	232.3	230.0	232.8	241.9	242.3	238.0
1959 ...	240.6	234.8	235.5	241.4	247.4	250.5	243.1	234.6	231.9	235.3	240.9	240.3	239.5
1960 ...	236.2	231.8	231.9	238.6	241.6	245.9	245.7	239.2	235.4	236.1	242.6	243.4	238.8
1961 ...	240.6	235.2	235.5	240.4	243.5	251.6	247.1	239.0	233.2	234.8	239.6	242.7	240.2
1962 ...	240.8	237.5	237.0	241.1	245.5	249.4	247.2	241.1	234.7	240.0	244.1	244.6	241.9

1/ Estimates based on actual weights reported by packers under Federal inspection.

Table 127-130.--Live weight of livestock slaughtered: Estimated average of slaughter under Federal inspection, 1959 to date 1/

HOGS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
1963 ...	242.8	236.6	234.6	238.0	242.9	246.4	247.0	238.5	234.7	236.3	244.1	245.0	240.4
1964 ...	244.1	238.5	237.7	241.6	246.3	251.1	249.0	242.0	238.1	243.4	245.6	245.9	243.3
1965 ...	241.3	234.7	234.5	239.0	243.0	247.0	241.7	237.2	235.6	240.1	244.2	244.9	240.1
1966 ...	243.4	239.8	240.3	245.4	251.1	253.5	247.0	239.9	236.8	239.9	246.3	246.4	243.9

A-II.3a Hog Prices

Table 203A.--Pork: Live animal and wholesale prices, wholesale and retail values

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
LIVE ANIMAL PRICE 1/													
1949	21.36	20.94	21.48	19.14	19.26	21.51	22.30	21.91	20.95	18.15	16.29	15.97	19.94
1950	16.40	17.56	16.72	16.52	19.57	20.39	24.22	24.32	21.98	19.72	18.42	19.30	19.59
1951	21.55	23.02	22.12	21.56	21.61	22.74	23.17	22.72	20.94	20.67	18.72	18.57	21.45
1952	18.42	18.02	17.36	17.31	21.21	20.96	22.63	22.24	20.28	19.18	17.19	17.47	19.36
1953	19.04	20.08	21.00	22.32	24.58	25.39	26.41	24.80	24.89	21.62	21.16	24.58	22.99
1954	25.94	26.25	26.36	27.84	27.15	25.25	23.47	22.94	20.01	18.96	19.24	18.31	23.48
1955	17.84	17.06	16.65	17.49	18.08	20.24	18.10	16.43	16.28	14.67	12.61	11.52	16.41
1956	12.18	12.84	13.44	15.44	16.81	17.00	16.82	17.07	16.42	15.88	15.23	17.24	15.53
1957	18.29	17.38	17.60	18.34	18.76	20.18	21.29	21.42	19.61	17.53	17.46	19.25	18.93
1958	19.69	20.54	21.54	21.20	23.06	23.68	23.52	21.44	20.60	19.32	18.87	18.72	21.02
1959	17.38	16.15	16.44	16.73	16.94	16.83	14.90	14.67	13.84	13.16	13.06	12.42	15.21
1960	13.09	13.95	15.78	16.48	16.78	17.56	18.25	17.11	16.84	17.82	17.97	18.21	16.65
1961	18.03	18.54	17.91	17.58	17.28	17.52	18.31	18.46	18.33	17.40	16.55	17.39	17.78
1962	17.62	17.04	16.69	16.56	16.22	17.76	18.85	18.84	19.10	17.27	17.18	17.06	17.52
WHOLESALE VALUE 2/													
1949	25.59	25.01	25.78	24.77	23.88	25.42	25.96	27.06	26.77	23.90	21.25	20.15	24.63
1950	20.26	21.50	21.32	20.99	23.53	24.16	27.89	28.42	27.52	24.38	23.21	24.65	23.99
1951	25.98	27.32	26.81	25.97	26.40	26.48	26.23	27.18	26.98	26.57	23.45	23.05	26.04
1952	22.80	22.30	22.51	22.40	24.95	25.01	26.11	27.80	25.51	24.37	22.22	21.89	23.99
1953	23.39	24.69	25.43	26.55	28.72	29.23	30.37	30.66	30.04	27.23	25.73	28.93	27.58
1954	30.68	30.51	31.03	31.85	31.68	29.80	28.76	27.96	25.64	23.69	24.60	23.66	28.32
1955	23.18	22.46	21.46	22.58	22.92	24.69	23.94	22.65	22.46	20.74	19.53	18.29	22.08
1956	18.28	19.04	18.88	20.46	21.75	22.07	22.09	22.18	22.40	21.50	20.67	22.29	20.97
1957	23.59	23.55	23.22	23.75	24.09	25.21	26.48	27.15	25.84	23.37	23.36	24.46	24.51
1958	25.32	26.18	27.07	27.24	28.18	28.90	29.12	27.58	26.51	25.44	24.68	24.11	26.69
1959	23.14	21.94	21.42	21.85	21.95	22.09	20.72	20.30	20.60	19.54	19.08	18.40	20.92
1960	18.94	19.25	20.86	21.54	21.61	22.30	22.95	22.90	22.10	22.98	23.27	23.34	21.84
1961	22.97	23.64	23.26	22.65	22.00	22.02	22.63	23.11	23.63	22.65	21.71	22.13	22.70
1962	22.34	22.16	21.90	21.26	21.36	22.42	23.60	23.98	24.88	22.70	22.67	22.54	22.65
WHOLESALE PRICE 3/													
1949	46.21	45.43	47.17	45.94	44.21	47.38	48.85	50.19	49.17	43.87	38.96	37.09	45.37
1950	37.40	39.96	39.13	38.70	43.19	44.51	51.36	51.21	49.36	43.89	41.11	43.32	43.60
1951	45.43	47.83	46.81	45.49	46.38	46.83	46.91	48.49	48.21	47.34	41.66	40.94	46.03
1952	40.98	40.45	41.30	41.11	46.45	46.87	48.74	52.11	48.28	46.06	41.74	41.09	44.60
1953	44.17	46.94	47.91	49.77	53.91	55.57	57.34	56.70	54.30	48.40	46.53	52.17	51.14
1954	55.79	55.06	55.83	56.96	57.23	54.19	51.96	50.85	46.36	43.00	44.40	42.91	51.21
1955	42.49	41.32	39.87	41.81	43.04	46.72	44.87	43.06	42.32	38.66	35.26	33.23	41.05
1956	33.55	35.02	34.89	37.60	39.64	41.30	41.66	41.38	41.53	39.17	37.57	40.45	38.65
1957	43.30	42.53	42.26	43.49	44.91	47.21	49.45	50.64	47.40	43.09	42.49	45.09	45.16
1958	47.60	48.34	50.04	50.47	51.85	53.38	54.04	50.77	49.04	46.55	45.36	44.51	49.33
1959	43.55	41.00	40.28	41.32	41.55	42.26	39.70	39.30	39.62	37.53	36.34	35.23	39.81
1960	36.34	37.19	40.53	41.26	41.34	42.77	43.51	43.11	42.26	43.49	43.43	43.55	41.56
1961	42.96	43.94	42.85	41.53	40.77	40.96	42.53	43.85	44.87	42.43	40.49	41.83	42.42
1962	42.32	41.68	41.26	40.38	40.09	42.28	44.81	45.51	46.64	42.87	42.62	42.62	42.76
RETAIL VALUE 4/													
1949	56.40	54.30	55.90	56.90	54.80	57.70	56.70	59.30	60.70	56.90	51.40	48.90	55.82
1950	43.60	50.00	50.70	50.00	54.00	56.00	60.30	61.30	62.40	57.40	54.90	55.40	55.08
1951	57.90	59.30	59.40	58.70	59.10	59.60	59.90	60.80	60.60	60.50	58.30	55.80	59.16
1952	55.70	55.00	54.40	54.00	55.70	58.40	58.80	63.00	62.00	60.80	56.70	55.30	57.48
1953	55.60	57.40	58.90	60.10	64.40	68.10	69.70	69.50	69.20	65.40	60.40	63.50	63.52
1954	67.70	68.10	68.10	68.90	69.20	68.30	65.80	63.80	62.80	59.90	58.20	57.40	64.85
1955	56.50	55.60	54.00	53.90	55.00	57.60	57.90	56.50	57.30	55.10	50.60	48.10	54.84
1956	46.70	47.90	47.50	49.60	51.00	54.80	54.60	55.10	55.90	55.20	53.10	53.70	52.09
1957	55.70	58.10	56.60	57.40	59.00	61.80	64.20	67.00	65.20	60.40	58.10	59.20	60.22
1958	61.90	63.10	64.20	65.10	65.60	67.90	69.10	68.20	65.30	63.40	61.80	61.40	64.75
1959	61.10	58.70	57.50	58.00	58.20	58.50	58.10	56.50	57.20	55.50	53.80	52.20	57.11
1960	51.90	51.90	53.00	54.80	56.10	57.60	59.10	59.80	58.70	59.10	58.70	59.20	56.66
1961	59.50	59.70	59.50	59.10	57.90	57.90	59.10	60.10	61.00	60.50	58.40	57.70	59.20
1962	58.20	58.10	57.40	57.90	57.50	58.00	60.10	61.90	64.60	61.20	59.60	59.10	59.45

1/ Average price of 200-220 pound barrows and gilts, Chicago.
2/ Wholesale value of carcass and by-products.
3/ Value of 100 pounds of pork cuts at Chicago computed from price quotations of individual cuts in the Livestock Market News and the National Provisioner.
4/ Calculated from average retail prices of major retail cuts of meat in urban areas, published by the Bureau of Labor Statistics.

A-II.3b **Hog Prices**

Table 203A.--Pork: Live animal and wholesale prices, wholesale and retail values

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
LIVE ANIMAL PRICE 1/													
1959...	17.38	16.15	16.44	16.73	16.94	16.88	14.90	14.67	13.84	13.16	13.06	12.42	15.21
1960...	13.09	13.95	15.78	16.48	16.78	17.56	18.25	17.11	16.84	17.82	17.97	18.21	16.65
1961...	18.03	18.54	17.91	17.58	17.28	17.52	18.31	18.46	18.33	17.40	16.55	17.39	17.78
1962...	17.62	17.04	16.69	16.56	16.22	17.76	18.85	18.84	19.10	17.27	17.18	17.06	17.52
1963...	16.29	15.52	14.36	14.22	15.70	17.83	18.91	17.74	16.18	15.81	13.92	15.16	15.97
1964...	15.39	15.28	15.08	14.90	15.85	16.84	17.91	17.52	17.28	16.06	15.30	16.48	16.16
1965...	16.75	17.92	17.40	18.02	20.04	23.65	24.72	24.74	22.89	23.97	24.90	29.32	22.03
1966...	29.08	29.15	25.30	24.25	23.58	25.80	25.44	26.40	24.59	23.08	20.78	21.28	24.89
WHOLESALE VALUE 2/													
1959...	24.42	23.13	22.72	23.32	23.32	23.52	22.23	21.90	22.19	21.11	20.53	19.77	22.35
1960...	20.31	20.77	22.63	23.14	23.06	23.87	24.51	24.51	23.92	24.48	24.64	24.50	23.36
1961...	24.23	25.14	24.72	24.01	23.33	23.18	23.95	24.69	25.26	24.02	23.02	23.50	24.09
1962...	23.72	23.50	23.28	22.72	23.09	23.76	25.00	25.47	26.09	24.37	24.19	24.03	24.10
1963...	22.98	22.47	21.48	20.71	21.66	23.82	24.82	24.51	23.44	22.99	22.18	22.27	22.78
1964...	22.28	22.04	22.01	21.71	21.64	22.76	23.91	24.40	24.24	23.15	22.43	22.68	22.77
1965...	23.19	23.73	24.03	24.84	25.46	28.43	30.24	31.30	30.33	30.01	30.63	34.91	28.08
1966...	34.47	34.58	32.78	30.94	29.95	31.35	31.82	32.42	30.53	30.65	28.38	28.77	31.39
WHOLESALE PRICE 3/													
1959...	43.53	40.92	40.24	41.26	41.44	42.13	39.64	39.18	39.58	37.45	36.33	35.15	39.74
1960...	36.19	37.07	40.36	41.08	41.14	42.67	43.59	43.29	42.49	43.37	43.35	43.27	41.49
1961...	42.79	43.95	42.87	41.69	40.98	41.06	42.53	43.81	44.87	42.67	40.66	41.83	42.48
1962...	42.25	41.60	41.06	40.16	40.88	42.21	44.63	45.46	46.60	42.99	42.59	42.59	42.75
1963...	40.64	39.48	37.71	36.29	38.31	42.41	44.39	43.87	41.71	40.82	39.14	39.28	40.34
1964...	39.38	38.66	38.62	38.05	37.97	40.20	42.49	43.33	42.81	40.58	38.92	39.46	40.04
1965...	40.48	41.52	42.01	43.45	44.65	50.53	53.66	55.33	53.48	52.82	53.68	62.11	49.48
1966...	60.64	60.94	57.31	53.92	52.06	55.23	56.19	57.33	53.36	53.72	49.21	50.69	55.05
RETAIL VALUE 4/													
1959...	60.90	58.50	57.30	57.80	58.00	58.30	57.90	56.30	57.00	55.30	53.60	52.00	56.91
1960...	51.70	51.70	52.80	54.60	55.90	57.40	58.90	59.60	58.50	58.90	58.50	59.00	56.46
1961...	59.30	59.50	59.30	58.90	57.70	57.70	58.90	59.90	60.80	60.30	58.20	57.40	58.99
1962...	58.00	57.90	57.20	57.70	57.30	57.80	59.90	61.70	64.30	61.00	59.40	58.90	59.26
1963...	58.50	57.60	56.50	54.90	54.70	56.40	58.80	59.90	59.60	57.90	56.50	56.10	57.30
1964...	55.80	55.80	55.30	54.90	54.60	54.80	56.70	57.60	59.60	58.30	56.90	56.20	56.38
1965...	56.40	56.90	57.20	57.40	58.00	63.80	68.40	70.30	70.50	69.70	69.40	72.90	64.24
1966...	77.60	78.80	78.00	73.30	71.60	72.40	73.00	73.60	74.10	72.70	69.80	68.00	73.58

1/ Average price of 200-220 pound barrows and gilts, Chicago.

2/ Wholesale value of carcass and by-products.

3/ Value of 100 pounds of pork and sausage at Chicago computed from price quotations of individual cuts in the *Livestock Market News* and the *National Provisioner*.

4/ Calculated from average retail prices of major retail cuts of meat in urban areas, published by the Bureau of Labor Statistics.

A-II.3c

Table 182.--Hogs: Average price received by farmers, per 100 pounds, 48 States, by months, 1940 to date

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Weighted average 1/
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
1940......	5.17	4.96	4.87	4.91	5.37	4.78	5.84	5.90	6.20	5.85	5.61	5.61	5.39
1941......	7.47	7.29	7.16	8.16	8.31	9.12	10.30	10.50	11.20	10.10	9.70	10.30	9.09
1942......	10.70	11.90	12.50	13.50	13.30	13.40	13.80	14.10	13.60	14.10	13.40	13.30	13.00
1943......	14.10	14.60	14.70	14.30	13.90	13.60	13.20	13.70	14.10	14.00	12.90	12.80	13.70
1944......	12.80	12.90	12.90	13.00	12.70	12.60	12.70	13.50	13.60	13.80	13.50	13.40	13.10
1945......	13.80	14.00	14.00	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.20	14.20	14.00
1946......	14.10	14.20	14.20	14.20	14.30	14.30	17.20	20.80	16.10	22.20	23.00	22.80	17.50
1947......	21.90	24.30	26.50	23.90	22.20	22.10	22.00	23.60	26.70	27.10	24.30	25.20	24.10
1948......	26.60	21.60	21.50	20.30	19.90	22.90	25.20	26.90	27.40	24.70	21.80	20.90	23.10
1949......	19.60	19.30	20.00	18.30	17.90	18.80	18.60	19.40	19.80	17.60	15.60	14.80	18.10
1950......	15.10	16.60	16.00	15.70	18.30	18.20	20.90	21.70	21.30	19.20	17.80	17.80	18.00
1951......	20.00	21.90	21.20	20.60	20.40	20.90	20.50	20.90	19.80	20.20	18.10	17.60	20.00
1952......	17.30	17.10	16.60	16.40	19.20	19.40	19.70	20.60	19.00	18.50	16.60	16.10	17.80
1953......	17.90	19.30	20.20	21.00	23.10	22.80	23.70	23.30	23.90	21.30	20.30	23.00	21.40
1954......	24.70	25.30	25.00	26.40	24.70	21.50	20.40	21.10	19.70	18.40	18.50	17.00	21.60
1955......	16.80	16.30	15.50	16.60	16.40	17.70	16.40	15.70	15.70	14.50	12.10	10.60	15.00
1956......	11.00	12.10	12.40	14.40	15.40	15.70	15.30	16.20	15.70	15.50	14.30	16.20	14.40
1957......	17.30	16.80	16.90	17.40	17.40	18.40	19.30	20.20	19.10	17.00	16.60	17.80	17.80
1958......	18.50	19.50	20.30	21.20	21.10	21.60	21.70	20.80	19.90	18.50	17.90	17.50	19.60
1959......	16.40	15.40	15.50	15.50	15.40	14.90	13.40	13.80	13.30	12.60	12.10	11.30	14.10
1960......	12.10	13.00	15.00	15.50	15.40	16.00	16.60	16.30	15.70	16.70	16.60	16.50	15.30
1961......	16.70	17.60	17.10	16.80	16.10	15.80	16.60	17.30	17.50	16.60	15.70	16.10	16.60
1962......	16.50	16.30	15.90	15.50	15.20	15.90	17.00	17.50	18.10	16.60	16.20	15.70	16.30
1963......													
1964......													

1/ Computed by weighting State weighted average prices by quantities sold.

Table 182.--Hogs: Average price received by farmers, per 100 pounds, 48 States, by months, 1958 to date

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Weighted average 1/
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
1958...	18.50	19.50	20.30	21.20	21.10	21.60	21.70	20.80	19.90	18.50	17.90	17.50	19.60
1959...	16.40	15.40	15.50	15.50	15.40	14.90	13.40	13.80	13.30	12.60	12.10	11.30	14.10
1960...	12.10	13.00	15.00	15.50	15.40	16.00	16.60	16.30	15.70	16.70	16.60	16.50	15.30
1961...	16.70	17.60	17.10	16.80	16.10	15.80	16.60	17.30	17.50	16.60	15.70	16.10	16.60
1962...	16.50	16.30	15.90	15.50	15.20	15.90	17.00	17.50	18.10	16.60	16.20	15.70	16.30
1963...	15.40	14.80	13.80	13.50	14.40	16.10	17.10	16.70	15.50	15.20	14.20	13.60	14.90
1964...	14.30	14.30	14.20	14.00	14.30	14.90	16.00	15.80	16.20	15.10	14.00	14.80	14.80
1965...	15.50	16.40	16.40	16.90	19.70	22.40	23.20	23.70	22.10	22.90	23.50	26.90	20.60
1966...	27.30	27.20	24.00	22.10	22.30	23.20	23.20	24.50	22.30	21.20	19.30	18.90	22.80

1/ Computed by weighting State weighted average prices by quantities sold.

A-II.3d Hog Prices

Table 187.--Price per 100 pounds received by farmers, parity price, and price received as percentage of parity, meat animals, 48 States, 1940 to date

Year	Hogs		
	Price received by farmers 1/	Parity price 2/	Percentage of parity
	Dol.	Dol.	Pct.
1940..	5.42	9.01	60
1941..	9.13	9.52	96
1942..	13.10	10.80	121
1943..	13.80	11.60	120
1944..	13.10	12.20	108
1945..	14.10	12.40	113
1946..	17.30	13.90	124
1947..	24.20	16.70	145
1948..	23.30	18.00	129
1949..	18.30	17.60	104
1950..	18.20	19.20	95
1951..	20.20	21.30	95
1952..	18.00	21.40	84
1953..	21.60	20.20	107
1954..	21.90	20.70	106
1955..	15.40	21.20	73
1956..	14.50	21.30	68
1957..	17.80	21.90	81
1958..	19.80	22.10	90
1959..	14.10	21.60	65
1960..	15.40	21.30	72
1961..	16.70	21.30	78
1962..	16.40	21.70	76
1963..	15.00	22.40	67
1964..	14.80	21.70	68
1965..	20.80	21.40	97
1966..	23.00	22.80	101

AII.4 Hog-Corn Price Ratio

Table 188.--Hog-corn price ratio, by months, 48 States, 1940 to date 1/

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average 2/
1940.	9.7	9.1	8.7	8.4	8.5	7.5	9.3	9.4	10.0	9.8	9.9	10.3	9.2
1941.	13.3	13.0	12.5	13.2	12.6	13.4	14.8	15.0	15.9	15.6	15.2	15.4	14.2
1942.	14.7	15.5	16.0	16.9	16.3	16.3	16.6	16.9	16.4	18.2	17.7	16.5	16.5
1943.	16.0	16.2	15.5	14.3	13.4	12.8	12.2	12.6	12.9	13.1	12.3	11.5	13.6
1944.	11.3	11.4	11.5	11.3	11.0	11.0	10.9	11.5	11.7	12.2	12.7	12.6	11.6
1945.	12.9	13.2	13.1	13.2	13.1	12.7	12.6	12.4	12.6	12.5	12.8	13.0	12.8
1946.	12.8	12.8	12.5	12.2	10.6	10.1	8.8	11.6	9.3	13.1	18.1	18.7	12.6
1947.	18.1	19.8	17.7	14.7	14.0	11.9	10.8	10.8	11.1	12.2	11.1	10.6	13.6
1948.	10.8	11.2	10.2	9.3	9.2	10.6	12.5	14.1	15.4	17.9	18.0	17.0	13.0
1949.	15.7	17.2	16.9	15.0	14.7	15.5	14.9	16.4	17.1	16.1	15.3	13.1	15.7
1950.	13.1	14.3	13.4	12.5	13.7	13.4	14.5	15.1	14.8	14.0	13.0	12.3	13.7
1951.	13.0	13.7	13.2	12.7	12.4	12.9	12.6	12.7	12.0	12.3	11.2	10.5	12.4
1952.	10.3	10.4	10.1	9.8	11.3	11.2	11.4	11.9	11.1	12.1	11.4	10.7	11.0
1953.	12.1	13.5	13.8	14.4	15.5	15.6	16.1	15.7	15.9	15.9	15.3	16.3	15.0
1954.	17.4	17.7	17.4	18.2	16.8	14.4	13.6	13.8	12.9	12.7	13.5	12.2	15.0
1955.	12.0	11.6	11.4	12.2	11.7	12.6	11.7	12.1	12.7	12.7	11.1	9.2	11.8
1956.	9.5	10.3	10.3	10.9	11.1	11.1	10.7	11.2	11.0	13.0	11.8	13.3	11.2
1957.	14.1	14.1	14.1	14.4	14.1	15.1	15.7	16.4	16.6	16.0	16.9	18.1	15.5
1958.	19.9	20.4	20.3	18.0	18.3	18.2	18.4	17.6	17.6	17.8	19.0	17.2	18.6
1959.	16.1	14.8	14.6	13.7	13.4	12.8	11.9	12.2	12.2	12.7	12.3	11.8	13.2
1960.	12.4	13.1	15.0	14.8	14.4	14.8	15.2	15.2	14.8	16.9	19.2	18.1	15.3
1961.	17.3	17.6	16.9	17.4	15.8	15.3	15.8	16.6	16.8	16.3	16.7	17.0	16.6
1962.	17.4	17.1	16.4	15.7	14.8	15.4	16.3	17.2	17.4	16.3	17.3	15.7	16.4
1963.	15.0	14.0	12.9	12.6									
1964.													

1/ Number of bushels of corn equal in value to 100 pounds of hog, live weight. 2/ Simple average.

Table 188.--Hog-corn price ratio, by months, 48 States, 1958 to date 1/

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Simple average
1958...	19.9	20.4	20.3	18.0	18.3	18.2	18.4	17.6	17.6	17.8	19.0	17.2	18.6
1959...	15.9	14.8	14.6	13.7	13.3	12.8	11.9	12.2	12.2	12.7	12.2	11.6	13.2
1960...	12.1	12.9	14.7	14.6	14.3	14.7	15.2	15.2	14.8	16.8	18.4	18.0	15.1
1961...	17.2	17.4	16.9	17.4	15.8	15.3	15.8	16.6	16.8	16.3	15.8	16.2	16.5
1962...	16.6	16.4	15.9	15.2	14.6	15.3	16.2	17.0	17.4	16.1	16.4	15.1	16.0
1963...	14.4	13.6	12.5	12.3	13.0	13.9	14.4	14.0	12.8	13.7	13.5	12.5	13.4
1964...	12.8	12.9	12.6	12.2	12.2	12.8	14.3	14.1	13.8	13.4	13.1	12.8	13.1
1965...	13.1	13.7	13.6	13.7	15.6	17.9	19.0	20.1	18.7	20.8	22.6	23.8	17.7
1966...	22.9	22.7	20.5	18.6	18.4	19.3	18.3	18.3	16.5	16.4	15.3	14.7	18.5
													16.2

1/ Number of bushels of corn equal in value to 100 pounds of hog, live weight.

A-II.5 Hog Inventory

Table 41.--Hogs: Inventory numbers, pig crops, disposition, production and income, United States, 1940 to date [1]

Year	On hand Jan. 1 [2]	Pigs saved	Inshipments	Marketings [3]	Farm slaughter	Deaths	Production [4]	Marketings [3]	Price per 100 pounds	Value of production [4]	Cash receipts [5]	Value of home consumption	Gross income	Cost of inshipments
	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 pounds	1,000 pounds	Dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars
1940	61,165	79,866	607	64,262	14,155	8,868	17,043,404	14,837,309	5.39	919,927	835,618	148,547	984,165	4,233
1941	54,353	84,952	741	57,695	12,789	8,955	17,489,485	13,765,340	9.09	1,576,855	1,302,404	215,795	1,518,199	7,621
1942	60,607	104,903	600	67,423	12,533	12,273	21,105,133	16,300,303	13.04	2,734,255	2,198,015	309,415	2,507,430	8,642
1943	73,881	121,807	771	83,187	14,016	15,515	25,374,715	20,748,145	13.69	3,466,520	2,929,215	372,797	3,302,012	11,645
1944	83,741	86,659	658	86,289	13,551	11,845	20,583,755	20,824,595	13.10	2,674,286	2,800,202	332,635	3,132,837	9,397
1945	59,373	86,827	464	61,035	13,631	10,692	18,843,444	15,493,614	14.00	2,636,697	2,262,963	376,754	2,639,717	7,144
1946	61,306	82,694	464	64,409	13,721	9,544	18,744,289	15,984,074	17.50	3,269,536	2,916,591	483,741	3,400,332	8,794
1947	56,810	83,289	497	63,499	12,072	10,435	18,159,250	15,722,320	24.10	4,356,461	3,926,412	596,373	4,522,785	12,815
1948	54,590	83,826	459	61,790	11,200	9,628	18,222,058	15,279,948	23.10	4,204,865	3,659,884	542,249	4,202,133	11,405
1949	56,257	93,244	541	69,249	10,236	11,705	19,457,476	16,747,211	18.10	3,529,243	3,124,726	388,479	3,513,205	10,670
1950	58,937	97,381	580	72,673	9,720	12,236	20,213,732	17,397,682	18.00	3,637,893	3,214,247	355,382	3,569,629	11,344
1951	62,269	100,586	755	79,142	9,479	12,872	21,436,178	19,006,543	20.00	4,291,192	3,889,145	388,509	4,277,654	16,252
1952	62,117	88,829	740	80,488	8,882	10,601	19,726,620	19,082,155	17.80	3,517,803	3,464,118	328,730	3,792,848	14,356
1953	51,755	77,914	812	68,572	7,455	9,340	16,800,404	16,026,179	21.40	3,585,019	3,483,040	335,897	3,818,937	18,477
1954	45,114	86,830	1,116	66,012	6,668	9,906	18,218,278	15,761,848	21.60	3,941,234	3,454,542	321,554	3,776,096	25,747
1955	50,474	95,729	1,398	75,400	6,835	10,012	20,153,606	17,848,736	15.00	3,034,754	2,693,958	241,133	2,935,091	21,830
1956	55,354	89,426	1,532	79,091	6,551	8,773	19,089,436	18,302,376	14.40	2,741,025	2,637,734	213,821	2,851,555	24,213
1957	51,897	87,362	1,515	74,087	6,041	9,129	18,413,031	17,164,746	17.80	3,270,058	3,062,318	243,647	3,305,955	28,431
1958	51.517	93,533	2,077	73,419	5,857	9,806	19,179,682	17,079,447	19.60	3,765,395	3,366,859	267,392	3,634,251	36,559
1959	58,045	99,395	2,348	84,379	6,024	10,359	21,272,858	19,747,078	14.10	2,996,318	2,783,899	201,830	2,935,729	28,402
1960	59,026	88,138	2,500	79,831	5,114	9,223	19,203,234	18,622,151	15.30	2,946,440	2,864,880	182,808	3,047,688	31,467
1961	55,560	92,715	2,293	80,326	4,639	8,984	20,166,822	18,917,418	16.60	3,355,213	3,152,383	181,785	3,334,168	30,450
1962	56,619	93,608	2,639	81,743	4,093	9,037	20,274,620	19,310,335	16.30	3,311,953	3,161,521	156,342	3,317,863	35,893
1963	57,993	94,056	2,657	86,163	3,795	7,991	20,960,460	20,273,936	14.90	3,128,458	3,033,284	134,868	3,168,152	32,117
1964	56,757	87,544	2,718	86,086	3,269	6,872	20,216,732	20,487,965	14.80	2,988,624	3,033,518	116,089	3,149,607	31,724
1965	50,792	78,940	2,385	76,079	2,613	6,011	18,055,208	17,921,484	20.60	3,715,956	3,693,341	128,241	3,821,582	36,369
1966	47,414	85,895	2,595	77,076	1,317	6,476	19,105,067	18,100,820	22.80	4,353,516	4,124,184	136,619	4,260,803	48,399
1967														

---

[1] Balance sheet estimates. Total of marketings, farm slaughter, deaths and on hand end of year equals total of births, inshipments, and on hand beginning of year. For cattle and calves and hogs, includes Alaska and Hawaii beginning 1961. For sheep and lambs, includes Alaska beginning 1961; Hawaii not available. [2] All cattle and calves. [3] Excludes interfarm sales. [4] Adjustments made for inshipments and changes in inventory. [5] Receipts from marketings and from sales of farm slaughtered meats. [6] All hogs and pigs. [7] All sheep and lambs. [8] Data for 1966 not comparable with previous year due to change in definition to include custom slaughtering in plants for farmers as part of the commercial meat production estimates beginning with January 1966. [9] Beginning in 1965, sheep and lambs combined.

A II.6a Sows Farrowing, Pigs Saved Per Litter - Spring

Table 26.--December-May pig crop: Sows farrowing, pigs per litter, and pigs saved, 48 States, 1940 to date

Year	Sows farrowing													Pigs saved per litter	Pigs saved
	Number							Percentage of total							
	Total	Dec.	Jan.	Feb.	Mar.	Apr.	May	Dec.	Jan.	Feb.	Mar.	Apr.	May		
	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	Percent	Percent	Percent	Percent	Percent	Percent	Number	1,000 head
1940.	8,247	340	502	949	2,375	2,777	1,304	4.1	6.1	11.5	28.8	33.7	15.8	6.01	49,584
1941.	7,760	262	368	776	2,000	2,753	1,601	3.4	4.7	10.0	25.8	35.5	20.6	6.36	49,368
1942.	9,684	370	494	922	2,584	3,389	1,925	3.8	5.1	9.5	26.7	35.0	19.9	6.31	61,093
1943.	12,174	473	574	1,169	3,055	4,313	2,590	3.9	4.7	9.6	25.1	35.4	21.3	6.10	74,223
1944.	9,246	413	466	891	2,467	3,275	1,734	4.5	5.0	9.6	26.7	35.4	18.8	6.03	55,754
1945.	8,302	311	378	700	2,024	3,004	1,885	3.7	4.6	8.4	24.4	36.2	22.7	6.29	52,216
1946.	8,077	293	354	701	2,128	2,952	1,649	3.6	4.4	8.7	26.3	36.6	20.4	6.46	52,191
1947.	8,548	293	381	900	2,452	3,035	1,487	3.4	4.5	10.5	28.7	35.5	17.4	6.11	52,199
1948.	7,833	254	350	746	2,122	2,838	1,523	3.2	4.5	9.5	27.1	36.2	19.5	6.44	50,468
1949.	8,820	283	441	958	2,567	3,026	1,545	3.2	5.0	10.9	29.1	34.3	17.5	6.46	56,969
1950.	9,179	249	418	1,090	2,804	3,085	1,533	2.7	4.6	11.9	30.5	33.6	16.7	6.31	57,958
1951.	9,484	281	484	1,218	2,717	3,078	1,706	3.0	5.1	12.8	28.6	32.5	18.0	6.46	61,298
1952.	8,311	259	464	1,163	2,332	2,550	1,543	3.1	5.6	14.0	28.0	30.7	18.6	6.63	55,135
1953.	7,045	213	415	998	2,028	2,160	1,231	3.0	5.9	14.2	28.8	30.6	17.5	6.80	47,940
1954.	7,669	255	480	1,313	2,288	2,104	1,229	3.3	6.3	17.1	29.9	27.4	16.0	6.89	52,852
1955.	8,347	305	675	1,517	2,306	2,254	1,290	3.7	8.1	18.2	27.6	27.0	15.4	6.90	57,610
1956.	7,655	395	724	1,420	2,156	1,914	1,046	5.2	9.4	18.5	28.2	25.0	13.7	6.94	53,124
1957.	7,195	382	695	1,310	1,986	1,811	1,010	5.3	9.7	18.2	27.6	25.2	14.0	7.12	51,263
1958.	7,281	410	790	1,480	1,869	1,706	1,026	5.6	10.9	20.3	25.7	23.4	14.1	7.05	51,354
1959.	7,996	539	985	1,529	2,048	1,853	1,042	6.8	12.3	19.1	25.6	23.2	13.0	7.08	56,620
1960.	6,782	494	761	1,252	1,707	1,604	964	7.3	11.2	18.5	25.2	23.6	14.2	6.96	47,228
1961.	7,018	506	772	1,243	1,707	1,745	1,045	7.2	11.0	17.7	24.3	24.9	14.9	7.18	50,366
1962.	6,996	494	824	1,262	1,738	1,651	1,027	7.1	11.8	18.0	24.8	23.6	14.7	7.08	49,535
1963.	7,099	566	856	1,171	1,656	1,769	1,081	8.0	12.1	16.5	23.3	24.9	15.2	7.15	50,749
1964.	6,596	536	785	1,045	1,557	1,605	1,068	8.1	11.9	15.9	23.6	24.3	16.2	7.23	47,682
1965.	5,890	517	708	953	1,404	1,395	913	8.8	12.0	16.2	23.8	23.7	15.5	7.22	42,525
1966.	6,249	529	737	967	1,406	1,545	1,011	8.5	11.8	15.5	23.3	24.7	16.2	7.32	45,771

A II.6 Sows Farrowing - Fall

Table 27.--June-November pig crop: Sows farrowing, pigs per litter, and pigs saved, 48 States, 1940 to date

Year	Sows farrowing													Pigs saved per litter	Pigs saved
	Number							Percentage of total							
	Total	June	July	Aug.	Sept.	Oct.	Nov.	June	July	Aug.	Sept.	Oct.	Nov.		
	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	Percent	Percent	Percent	Percent	Percent	Percent	Number	1,000 head
1940.	4,763	552	470	908	1,552	904	377	11.6	9.9	19.0	32.6	19.0	7.9	6.36	30,282
1941.	5,535	551	531	982	1,751	1,157	563	10.0	9.6	17.7	31.6	20.9	10.2	6.43	35,584
1942.	6,840	769	699	1,190	2,154	1,398	630	11.3	10.2	17.4	31.5	20.4	9.2	6.40	43,810
1943.	7,565	1,108	932	1,453	2,304	1,247	521	14.6	12.3	19.2	30.5	16.5	6.9	6.29	47,584
1944.	4,882	769	562	905	1,486	802	358	15.7	11.5	18.6	30.5	16.4	7.3	6.33	30,905
1945.	5,429	778	598	1,024	1,662	974	393	14.3	11.0	18.9	30.6	18.0	7.2	6,38	34,611
1946.	4,704	667	522	871	1,449	820	375	14.2	11.1	18.5	30.8	17.4	8.0	6.49	30,503
1947.	4,866	640	552	1,000	1,501	833	340	13.2	11.3	20.6	30.8	17.1	7.0	6.39	31,090
1948.	5,070	727	570	985	1,525	871	392	14.3	11.3	19.4	30.1	17.2	7.7	6.58	33,358
1949.	5,568	731	618	1,172	1,760	901	386	13.1	11.1	21.1	31.6	16.2	6.9	6.52	36,275
1950.	5,927	711	609	1,286	1,893	1,005	423	12.0	10.3	21.7	31.9	17.0	7.1	6.65	39,423
1951.	5,955	809	664	1,328	1,803	977	374	13.6	11.1	22.3	30.3	16.4	6.3	6.60	39,233
1952.	5,067	785	632	1,164	1,504	705	277	15.5	12.5	23.0	29.7	13.9	5.4	6.65	33,694
1953.	4,479	649	589	1,122	1,239	609	271	14.5	13.2	25.0	27.7	13.6	6.0	6.69	29,974
1954.	5,014	769	709	1,280	1,308	641	307	15.4	14.1	25.5	26.1	12.8	6.1	6.78	33,978
1955.	5,599	755	832	1,378	1,479	796	359	13.5	14.9	24.6	26.4	14.2	6.4	6.81	38,119
1956.	5,181	666	711	1,264	1,411	762	367	12.9	13.7	24.4	27.2	14.7	7.1	7.01	36,302
1957.	5,112	735	759	1,183	1,330	744	361	14.4	14.8	23.1	26.0	14.6	7.1	7.06	36,099
1958.	5,887	829	912	1,400	1,504	820	422	14.1	15.5	23.8	25.5	13.9	7.2	7.17	42,179
1959.	6,128	954	978	1,414	1,559	808	415	15.5	16.0	23.1	25.4	13.2	6.8	6.98	42,775
1960.	5,839	875	872	1,288	1,499	862	443	15.0	14.9	22.0	25.7	14.8	7.6	7.02	40,988
1961.	5,918	939	893	1,249	1,475	898	464	15.9	15.1	21.1	24.9	15.2	7.8	7.16	42,347
1962.	6,098	933	890	1,318	1,565	913	479	15.3	14.6	21.6	25.7	15.0	7.8	7.23	44,073
1963.	5,987	971	943	1,211	1,491	909	462	16.2	15.8	20.2	24.9	15.2	7.7	7.23	43,307
1964.	5,525	959	861	1,083	1,379	811	432	17.3	15.6	19.6	25.0	14.7	7.8	7.21	39,862
1965.	5,006	855	749	944	1,251	768	439	17.1	15.0	18.8	25.0	15.3	8.8	7.27	36,415
1966.	5,487	917	886	1,014	1,356	845	469	16.7	16.1	18.5	24.7	15.4	8.6	7.25	39,755

1/ Includes Alaska and Hawaii beginning 1962.

A-II.7 Hogs Slaughtered

Table 89.--Commercial hog Number slaughtered, by months, 48 States, 1944 to date 1/

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head
						Hogs							
1944......:	9,189.9	8,602.2	8,434.6	7,389.2	7,864.6	7,255.7	5,855.4	5,334.4	4,758.0	5,622.5	6,833.5	7,377.2	84,517.2
1945......:	7,398.8	5,142.3	4,974.6	4,346.4	4,477.1	4,293.8	3,630.4	3,157.8	3,279.1	3,931.8	6,107.4	7,520.3	58,259.8
1946......:	6,986.9	6,479.3	5,382.8	5,750.7	5,566.7	3,299.6	5,438.3	4,094.5	802.2	4,491.7	7,207.8	6,799.5	62,300.0
1947......:	7,515.0	5,080.0	4,335.0	4,622.0	4,726.0	4,481.0	4,248.0	3,430.0	3,901.0	5,135.0	6,747.0	7,709.0	61,929.0
1948......:	6,598.6	4,855.3	4,796.6	4,476.5	4,564.3	5,119.4	3,748.8	3,088.0	3,674.6	5,049.3	6,455.6	7,242.0	59,669.0
1949......:	6,526.6	5,133.3	5,427.4	4,823.9	4,575.2	4,504.8	3,836.1	4,226.0	4,800.1	5,967.1	7,192.7	7,747.8	64,761.0
1950......:	7,108.1	5,309.6	6,192.0	5,339.1	5,320.0	5,035.5	4,091.9	4,505.8	5,066.5	6,179.8	7,342.3	8,052.8	69,543.4
1951......:	8,047.5	5,364.8	6,326.7	6,110.6	6,002.5	5,658.4	4,670.3	5,317.7	5,472.9	6,949.4	7,855.8	8,284.7	76,061.3
1952......:	8,415.2	7,164.1	7,140.1	6,562.7	5,621.8	5,255.6	4,657.1	4,641.5	5,478.7	6,878.0	7,098.7	8,776.6	77,690.1
1953......:	7,763.9	5,811.7	6,232.0	5,450.2	4,548.4	4,448.3	4,106.0	4,278.5	5,078.3	6,094.4	6,649.4	6,452.2	66,913.3-
1954......:	5,874.3	4,886.6	5,648.4	4,724.3	4,205.1	4,272.3	4,122.6	4,723.1	5,768.9	6,223.2	6,969.4	7,408.5	64,826.7
1955......:	6,810.0	5,761.3	6,714.2	5,449.3	5,097.8	4,607.7	4,197.1	5,422.6	6,158.0	7,225.8	8,100.1	8,672.2	74,216.1-
1956......:	8,032.2	7,101.7	7,514.1	6,259.7	5,865.3	5,177.2	5,064.0	5,524.0	5,967.3	7,507.1	7,705.2	6,789.5	78,513.3
1957......:	6,879.7	5,995.7	6,381.1	5,977.3	5,866.1	4,792.3	5,032.2	5,310.1	5,997.2	7,223.8	6,536.1	6,603.4	72,595.0
1958......:	6,711.7	5,416.9	5,791.4	5,918.8	5,300.2	5,011.0	5,160.9	5,345.5	6,163.3	6,978.5	6,220.0	6,946.8	70,965.0
1959......:	7,028.4	6,717.9	6,817.5	6,698.1	5,900.5	5,843.4	6,154.6	5,914.2	6,930.3	7,845.4	7,472.8	8,258.8	81,581.9
1960........:	7,793.9	7,015.7	7,345.2	6,594.0	6,513.2	6,104.8	5,178.8	6,214.3	6,223.8	6,460.5	6,796.6	6,795.5	79,036.3
1961........:	6,795.4	6,028.7	7,149.9	5,951.6	6,570.2	6,012.7	5,155.1	6,104.2	6,173.9	7,275.5	7,377.6	6,739.9	77,334.7
1962........:	7,158.9	6,239.1	7,196.7	6,590.4	6,746.0	5,951.3	5,569.8	6,172.1	5,642.2	7,716.5	7,398.1	6,953.2	79,334.3
1963........:	7,405.3	6,603.7	7,545.1	7,352.8	6,894.3	5,739.0	5,891.0	6,085.2	6,839.9	7,872.5	7,361.3	7,733.4	83,323.5
1964........:	8,006.4	6,828.7	7,409.5	7,441.5	6,356.2	5,932.8	5,798.0	5,707.9	6,563.0	7,797.2	7,486.2	7,690.8	83,018.5
1965........:	6,995.7	6,161.9	7,526.1	6,690.8	5,513.8	5,479.0	5,142.0	5,529.1	6,340.8	6,255.4	6,334.5	5,814.1	73,783.5
1966 2/.....:	5,533.0	5,408.4	6,717.3	6,138.7	5,719.7	5,481.0	4,943.8	5,943.3	6,750.7	6,944.3	7,175.3	7,255.1	74,010.6

1/ Includes slaughter under Federal Inspection and other commercial slaughter; excludes farm slaughter.

2/ Data for 1966 not comparable with previous year due to change in definition to include custom slaughtering in plants for farmers as part of the commercial meat production estimates beginning with January 1966.

A-II.8a Per Capita Meat Consumption

Table 7.--Meat: Per capita consumption, carcass and retail cut equivalent, 1909-63

Year	Skeletal meats 1/											Edible offals	Total red meat (retail weight), excl. game	Game 3/	Canned meat 4/
	Beef		Veal		Pork			Lamb and mutton		Total					
	Carcass weight 2/	Retail cut equivalent	Carcass weight 2/	Retail cut equivalent	Carcass weight 2/	Retail cut equivalent		Carcass weight 2/	Retail cut equivalent	Carcass weight 2/	Retail cut equivalent				
						Lean pork	Fat cuts								
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
1909	74.2	58.6	7.3	6.6	67.0	43.6	18.8	6.7	6.0	155.2	133.6	11.1	144.7	3.0	---
1910	70.4	55.6	7.2	6.6	62.3	40.5	17.4	6.5	5.8	146.4	125.9	10.3	136.2	2.8	---
1911	68.5	54.1	7.1	6.5	69.0	44.8	19.3	7.3	6.5	151.9	131.2	10.8	142.0	2.6	---
1912	64.6	51.0	6.9	6.3	66.7	43.4	18.7	7.7	6.9	145.9	126.3	10.3	136.6	2.5	---
1913	63.3	50.0	6.3	5.7	66.9	43.5	18.7	7.2	6.4	143.7	124.3	10.1	134.4	2.4	---
1914	62.0	49.0	5.8	5.3	65.1	42.3	18.2	7.1	6.3	140.0	121.1	9.6	130.7	2.3	---
1915	56.4	44.6	5.9	5.4	66.5	43.2	18.6	6.1	5.4	134.9	117.2	10.1	127.3	2.2	---
1916	58.9	46.5	6.4	5.8	69.0	44.8	19.3	5.8	5.2	140.1	121.6	10.6	132.2	2.3	---
1917	64.7	51.1	7.2	6.6	58.9	38.3	16.5	4.5	4.0	135.3	116.5	10.3	126.8	2.5	---
1918	68.5	54.1	7.3	6.6	61.0	39.6	17.1	4.8	4.3	141.6	121.7	10.6	132.3	2.6	---
1919	61.5	48.6	7.8	7.1	63.9	41.5	17.9	5.7	5.1	138.9	120.2	11.0	131.2	2.5	---
1920	59.1	46.7	8.0	7.3	63.5	41.3	17.8	5.4	4.8	136.0	117.9	10.2	128.1	2.4	---
1921	55.5	43.8	7.6	6.9	64.8	42.1	18.1	6.1	5.4	134.0	116.3	9.7	126.0	2.3	---
1922	59.1	46.7	7.8	7.1	65.7	42.7	18.4	5.1	4.5	137.7	119.4	10.0	129.4	2.4	---
1923	59.6	47.1	8.2	7.5	74.2	48.2	20.8	5.3	4.7	147.3	128.3	10.7	139.0	2.4	---
1924	59.5	47.0	8.6	7.8	74.0	48.1	20.7	5.2	4.6	147.3	128.2	10.5	138.7	2.3	---
1925	59.5	47.0	8.6	7.8	66.8	43.4	18.7	5.2	4.6	140.1	121.5	10.2	131.7	2.1	---
1926	60.3	47.6	8.2	7.5	64.1	41.7	17.9	5.4	4.8	138.0	119.5	9.7	129.2	1.9	---
1927	54.5	43.1	7.4	6.7	67.7	44.0	19.0	5.3	4.7	134.9	117.5	9.4	126.9	1.8	
1928	48.7	38.5	6.5	5.9	70.9	46.1	19.9	5.5	4.9	131.6	115.3	9.0	124.3	1.8	---
1929	49.7	39.3	6.3	5.7	69.6	45.2	19.5	5.6	5.0	131.2	114.7	9.0	123.7	1.6	---
1930	48.9	38.6	6.4	5.8	67.0	43.6	18.8	6.7	6.0	129.0	112.8	8.9	121.7	1.6	---
1931	48.6	38.4	6.6	6.0	68.4	44.5	19.2	7.1	6.3	130.7	114.4	9.2	123.6	1.6	---
1932	46.7	36.9	6.6	6.0	70.7	46.0	19.8	7.1	6.3	131.1	115.0	9.2	124.2	1.6	---
1933	51.5	40.7	7.1	6.5	70.7	46.0	19.8	6.8	6.1	136.1	119.1	9.3	128.4	1.6	---
1934	63.8	50.4	9.4	8.6	64.4	41.9	18.0	6.3	5.6	143.9	124.5	9.6	134.1	1.6	---
1935	53.2	42.0	8.5	7.7	48.4	31.5	13.5	7.3	6.5	117.4	101.2	8.1	109.3	1.6	---
1936	60.5	47.8	8.4	7.6	55.1	35.8	15.4	6.6	5.9	130.6	112.5	8.4	120.9	1.7	---
1937	55.2	43.6	8.6	7.8	55.8	36.3	15.6	6.6	5.9	126.2	109.2	8.8	118.0	1.7	3.2
1938	54.4	43.0	7.6	6.9	58.2	37.8	16.3	6.9	6.1	127.1	110.1	8.5	118.6	1.7	3.1
1939	54.7	43.2	7.6	6.9	64.7	42.1	18.1	6.6	5.9	133.6	116.2	8.9	125.1	1.7	3.9
1940	54.9	43.4	7.4	6.7	73.5	47.8	20.6	6.6	5.9	142.4	124.4	9.7	134.1	1.8	4.3
1941	60.9	48.1	7.6	6.9	68.4	44.5	19.2	6.8	6.1	143.7	124.8	10.1	134.9	2.1	5.3
1942	61.2	48.3	8.2	7.5	63.7	41.4	17.8	7.2	6.4	140.3	121.4	11.5	132.9	2.2	1.6
1943	53.3	42.1	8.2	7.5	78.9	51.3	22.1	6.4	5.7	146.8	128.7	12.4	141.1	2.2	3.4
1944	55.6	43.9	12.4	11.3	79.5	51.7	22.3	6.7	6.0	154.2	135.2	13.5	148.7	2.2	3.4
1945	59.4	46.9	11.9	10.8	66.6	43.3	18.6	7.3	6.5	145.2	126.1	12.6	138.7	2.2	4.9
1946	61.6	48.7	10.0	9.1	75.8	49.3	21.2	6.7	6.0	154.1	134.3	11.3	145.6	2.2	8.0
1947	69.6	55.0	10.8	9.8	69.6	45.2	19.5	5.3	4.7	155.3	134.2	11.2	145.4	2.0	7.2
1948	63.1	49.8	9.5	8.6	67.8	44.1	19.0	5.1	4.5	145.5	126.0	10.3	136.3	2.1	7.8
1949	63.9	50.5	8.9	8.1	67.7	44.0	19.0	4.1	3.6	144.6	125.2	10.1	135.3	2.3	7.2
1950	63.4	50.1	8.0	7.3	69.2	45.0	19.4	4.0	3.6	144.6	125.4	10.1	135.5	2.3	8.7
1951	56.1	44.3	6.6	6.0	71.9	46.7	20.1	3.4	3.0	138.0	120.1	9.9	130.0	2.4	8.9
1952	62.2	49.1	7.2	6.6	72.4	47.1	20.3	4.2	3.7	146.0	126.8	10.2	137.0	2.4	9.4
1953	77.6	61.3	9.5	8.6	63.5	41.3	17.8	4.7	4.2	155.3	133.2	10.8	144.0	2.4	10.0
1954	80.1	62.9	10.0	9.0	60.0	39.0	16.8	4.6	4.1	154.7	131.8	10.6	142.4	2.5	9.8
1955	82.0	64.0	9.4	8.4	66.8	43.4	18.7	4.6	4.1	162.8	138.6	11.0	149.6	2.6	10.2
1956	85.4	66.2	9.5	8.4	67.3	43.7	18.8	4.5	4.0	166.7	141.1	11.2	152.3	2.6	11.0
1957	84.6	65.1	8.8	7.7	61.1	39.7	17.1	4.2	3.7	158.7	133.3	10.8	144.1	2.6	10.6
1958	80.5	61.6	6.7	5.8	60.2	39.1	16.9	4.2	3.7	151.6	127.1	9.8	136.9	2.7	10.7
1959	81.4	61.9	5.7	4.9	67.6	43.9	18.9	4.8	4.3	159.5	133.9	10.1	144.0	2.6	10.7
1960	85.0	64.2	6.1	5.2	64.9	42.1	18.2	4.8	4.3	160.8	134.0	10.1	144.1	2.6	10.8
1961	87.8	65.9	5.6	4.7	62.0	40.3	17.4	5.1	4.5	160.5	132.8	10.1	142.9	2.6	11.5
1962	88.8	66.2	5.5	4.6	63.6	41.3	17.8	5.2	4.6	163.1	134.5	10.1	144.6	2.5	11.9
1963 5/	94.2	69.7	4.9	4.1	65.3	42.4	18.3	4.9	4.4	169.3	138.9	10.3	149.2	2.5	12.1

1/ Civilian consumption only, beginning 1941. Includes processed meats on a fresh basis. Carcass weight converted to retail weight equivalent using factors indicated in table 6.

2/ Approximately at wholesale level of distribution.

3/ Approximation of game birds and mammals and commercially raised rabbits.

4/ Net canned weight; federally inspected only; excludes soups. Canned meat is included in total skeletal meat; see footnote 1.

5/ Preliminary.

A-II.9 Per Capita Pork Consumption Quarterly - 1955-1965

Table 31.--Meats: Quarterly civilian consumption per capita, 1955-63 1/

Item and year	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual total
	Pounds	Pounds	Pounds	Pounds	Pounds
Pork					
1955	17.2	15.0	15.0	19.6	66.8
1956	18.6	15.6	15.1	18.0	67.3
1957	15.8	14.5	13.9	16.9	61.1
1958	15.0	14.1	14.2	16.9	60.2
1959	16.7	15.7	16.0	19.2	67.6
1960	17.5	15.6	15.1	16.7	64.9
1961	15.8	15.0	14.2	17.0	62.0
1962	16.3	15.4	14.5	17.4	63.6
1963	16.5	15.9	15.1	17.9	65.4
1964	16.6	15.6	15.3	17.9	65.4
1965	15.7	14.7	13.8	14.5	58.7

A-II.10 Population of Consumers

Table 100.--Population, 48 and 50 States: Total and number eating out of civilian food supplies, United States, 1909-64 1/

Year	Total, including Armed Forces overseas		Year	Total including Armed Forces overseas		Number eating out of civilian supplies 2/	
	January 1	July 1		January 1	July 1	January 1	July 1
	Millions	Millions		Millions	Millions	Millions	Millions
1909	89.7	90.5					
1910	91.5	92.4	1940	131.5	132.1	---	---
1911	93.2	93.9	1941	132.8	133.4	132.0	131.8
1912	94.7	95.3	1942	134.2	134.9	132.3	131.5
1913	96.4	97.2	1943	135.9	136.7	129.8	128.9
1914	98.2	99.1	1944	137.7	138.4	128.8	128.6
1915	99.9	100.5	1945	139.2	139.9	128.7	129.1
1916	101.3	102.0	1946	140.7	141.4	134.5	138.4
1917	102.7	103.4	1947	142.8	144.1	140.9	142.6
1918	104.0	104.6	1948	145.5	146.6	144.1	145.2
1919	104.8	105.1	1949	148.0	149.2	146.4	147.6
1920	105.7	106.5	1950	150.6	151.7	149.0	150.2
1921	107.6	108.5	1951	153.1	154.3	150.7	151.0
1922	109.4	110.1	1952	155.8	157.0	152.2	153.3
1923	111.1	112.0	1953	158.4	159.6	154.9	156.0
1924	113.1	114.1	1954	161.1	162.4	157.7	159.1
1925	115.0	115.8	1955	164.0	165.3	160.7	162.3
1926	116.7	117.4	1956	166.8	168.2	163.9	165.4
1927	118.3	119.0	1957	169.8	171.3	167.0	168.4
1928	119.8	120.5	1958	172.7	174.1	170.1	171.5
1929	121.2	121.8	1959	175.7	177.1	173.1	174.5
			48 States				
1930	122.5	123.1	1960	178.6	179.9	176.1	177.4
1931	123.6	124.0	1961	181.5	183.0	179.0	180.4
1932	124.5	124.8	1962	184.5	185.8	181.6	183.0
1933	125.2	125.6	1963	187.2	188.5	184.5	185.8
1934	126.0	126.4	1964	190.0	191.2	187.2	188.5
			50 States 3/				
1935	126.9	127.2	1960	179.4	180.7	176.8	178.2
1936	127.7	128.1	1961	182.3	183.8	179.8	181.2
1937	128.5	128.8	1962	185.3	186.7	182.5	183.8
1938	129.4	129.8	1963	188.2	189.4	185.4	186.6
1939	130.4	130.9	1964	190.8	192.1	188.1	189.3

1/ Estimates of the Bureau of the Census, not adjusted for underenumeration. In computing per capita food consumption, the population for the date closer to the midpoint of the year concerned was used (e.g., for consumption data on a calendar-year basis, July 1 population was used). Beginning 1941, data on military takings for most commodities were deducted from total domestic consumption and per capita figures were computed using the series for population eating out of civilian supplies; data on military takings prior to 1941 were not available.

2/ Estimates computed from data supplied by several Federal agencies. For the period January 1, 1941, through January 1, 1946, an adjustment was made to allow for members of the Armed Forces eating out of civilian supplies; these adjustments were originally estimated by OPA on the basis of data from several official sources. Beginning July 1946 data are the civilian population estimates of the Bureau of the Census.

3/ Includes Hawaii and Alaska. Unless otherwise indicated, data in this handbook include information from these States beginning 1960.

A-II.11a Monthly Supply and Distribution of Pork 1959-1961

Period	Commercially produced								Total 2/		
	Supply			Distribution							
							Civilian consumption			Civilian consumption	
	Production	Beginning stocks	Imports	Exports and shipments	Ending stocks	Military	Total	Per person 1/	Production	Total	Per person 1/
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Lb.	Mil. lb.	Mil. lb.	Lb.
1959											
January	965	206	19	12	240	14	924	5.3	—	—	—
February	907	240	14	13	316	14	818	4.7	—	—	—
March	918	316	16	11	337	18	886	5.1	—	—	—
1st quarter	2,790	206	51	36	337	46	2,628	15.2	3,119	2,922	16.9
April	920	337	20	11	381	19	866	5.0	—	—	—
May	823	381	16	11	365	16	828	4.8	—	—	—
June	825	365	17	10	313	13	871	5.0	—	—	—
2nd quarter	2,568	337	53	32	313	48	2,565	14.7	2,625	2,771	15.9
July	842	313	17	11	248	20	893	5.1	—	—	—
August	792	248	12	13	184	11	844	4.8	—	—	—
September	926	184	13	13	163	15	932	5.3	—	—	—
3rd quarter	2,560	313	42	37	163	46	2,669	15.3	2,622	2,815	16.1
October	1,060	163	12	12	185	14	1,024	5.8	—	—	—
November	1,028	185	13	14	224	13	975	5.5	—	—	—
December	1,125	224	15	12	264	14	1,074	6.1	—	—	—
4th quarter	3,213	163	40	38	264	41	3,073	17.5	3,744	3,406	19.4
Year	11,131	206	186	143	264	181	10,935	62.7	12,110	11,914	68.3
1960											
January	1,058	264	17	10	312	15	1,002	5.7	---	---	---
February	940	312	15	12	343	15	897	5.1	---	---	---
March	981	343	13	13	338	16	970	5.5	---	---	---
1st quarter	2,979	264	45	35	338	46	2,869	16.3	3,300	3,099	17.5
April	910	338	17	13	383	15	854	4.8	---	---	---
May	905	383	15	12	366	19	886	5.0	---	---	---
June	852	366	19	10	351	22	874	4.9	---	---	---
2nd quarter	2,667	338	51	35	351	56	2,614	14.8	2,712	2,775	15.7
July	724	351	17	8	294	12	778	4.4	---	---	---
August	850	294	14	10	221	15	912	5.1	---	---	---
September	845	221	14	12	158	14	896	5.0	---	---	---
3rd quarter	2,419	351	45	30	158	41	2,586	14.5	2,463	2,701	15.2
October	885	158	15	11	144	15	868	5.0	---	---	---
November	956	144	15	14	154	13	934	5.2	---	---	---
December	957	154	14	13	170	12	930	5.2	---	---	---
4th quarter	2,798	158	44	38	170	40	2,752	15.4	3,155	3,013	16.9
Year	10,863	264	185	138	170	183	10,821	61.0	11,630	11,588	65.3
1961											
January	947	170	15	13	201	15	903	5.0	---	---	---
February	823	201	14	12	235	16	775	4.3	---	---	---
March	980	235	19	11	244	15	964	5.4	---	---	---
1st quarter	2,750	170	48	36	244	46	2,642	14.7	3,031	2,847	15.9
April	823	244	13	11	270	15	784	4.4	---	---	---
May	923	270	13	13	269	16	908	5.0	---	---	---
June	854	269	16	11	240	14	874	4.9	---	---	---
2nd quarter	2,600	244	42	35	240	45	2,566	14.3	2,64[illegible]	2,709	15.1
July	723	240	15	12	189	17	760	4.2	---	---	---
August	842	189	15	10	137	16	883	4.9	---	---	---
September	838	137	14	11	128	21	829	4.6	---	---	---
3rd quarter	2,403	240	44	33	128	54	2,472	13.7	2,442	2,574	14.2
October	993	128	18	11	136	21	971	5.4	---	---	---
November	1,034	136	18	13	193	19	963	5.3	---	---	---
December	950	193	17	11	200	16	933	5.1	---	---	---
4th quarter	2,977	128	53	35	200	56	2,867	15.8	3,299	3,099	17.1
Year	10,730	170	187	139	200	201	10,547	58.5	11,412	11,229	62.3

A.11.11b Monthly Supply and Distribution of Pork 1962 & 1966

Period	Commercially produced								Total 2/		
	Supply			Distribution						Civilian consumption	
							Civilian consumption				
	Production	Beginning stocks	Imports	Exports and shipments	Ending stocks	Military	Total	Per person 1/	Production	Total	Per person 1/
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Lb.	Mil. lb.	Mil. lb.	Lb.
1962											
January	1,017	200	19	10	210	17	999	5.5	---	---	---
February	864	210	16	9	235	18	828	4.6	---	---	---
March	1,010	235	20	10	280	18	957	5.3	---	---	---
1st qtr.	2,891	200	55	29	280	53	2,784	15.3	3,139	2,957	16.3
April	932	280	17	11	316	17	885	4.9	---	---	---
May	964	316	20	11	339	19	931	5.1	---	---	---
June	853	339	19	14	295	16	886	4.8	---	---	---
2nd qtr.	2,749	280	56	36	295	52	2,702	14.8	2,787	2,840	15.6
July	798	295	18	11	234	18	848	4.6	---	---	---
August	867	234	17	12	182	17	907	5.0	---	---	---
September	787	182	15	8	139	16	821	4.5	---	---	---
3rd qtr.	2,452	295	50	31	139	51	2,576	14.1	2,491	2,675	14.6
October	1,092	139	20	10	161	21	1,059	5.8	---	---	---
November	1,052	161	17	14	212	18	986	5.4	---	---	---
December	993	212	18	12	230	15	966	5.2	---	---	---
4th qtr.	3,137	139	55	36	230	54	3,011	16.4	3,424	3,213	17.5
1966											
January	830	152	33	7	158	18	832	4.3			
February	809	158	34	10	186	25	780	4.1			
March	1,006	186	40	13	217	19	983	5.1			
1st qtr.	2,645	152	107	30	217	62	2,595	13.5	2,743	2,618	13.5
April	923	217	37	10	272	13	882	4.6		66	
May	875	272	28	11	268	28	868	4.5			
June	841	268	33	12	214	21	895	4.6			
2nd qtr.	2,639	217	98	33	214	62	2,645	13.7	2,645	2,751	14.2
July	747	214	28	9	179	14	787	4.1			
August	879	179	23	12	140	29	900	4.7			
September	991	140	28	11	151	22	975	5.0			
3rd qtr.	2,617	214	79	32	151	65	2,662	13.8	2,621	2,726	14.1
October	1,029	151	34	16	171	23	1,004	5.2			
November	1,094	171	31	14	206	22	1,054	5.4			
December	1,106	206	32	15	234	21	1,074	5.6			
4th qtr.	3,229	151	97	45	234	66	3,132	16.2	3,328	3,146	16.2
Year	11,130	152	381	140	234	255	11,034	57.2	11,337	11,241	58.0

A-II.11c Supply and Distribution of Pork -- Yearly

Table 212.--Supply and distribution of pork, excluding lard, annual 1940-62, by months 1962

Period	Commercially produced								Total 2/		
	Supply			Distribution						Civilian consumption	
	Production	Beginning stocks	Imports	Exports and shipments	Ending stocks	Military	Civilian consumption		Production	Total	Per person 1/
							Total	Per person 1/			
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Lb.	Mil. lb.	Mil. lb.	Lb.
	1	2	3	4	5	6	7	8	9	10	11
1940..	8,246	469	6	162	656	---	7,903	59.8	10,044	9,701	73.5
1941..	7,904	656	12	483	533	173	7,383	56.0	9,528	9,007	68.4
1942..	9,234	533	1	1,200	938	904	6,726	51.2	10,876	8,368	63.7
1943..	11,762	938	8	2,113	970	1,331	8,294	64.3	13,640	10,172	78.9
1944..	11,502	970	3/	1,714	487	1,843	8,428	65.5	13,304	10,230	79.5
1945..	8,843	487	2	873	428	1,287	6,744	52.2	10,697	8,598	66.6
1946..	9,220	428	3/	480	297	295	8,576	62.0	11,136	10,492	75.8
1947..	8,811	297	3/	132	518	230	8,228	57.7	10,502	9,919	69.6
1948..	8,486	518	1	85	469	180	8,271	57.0	10,055	9,840	67.8
1949..	8,875	469	3	110	474	183	8,580	58.1	10,286	9,991	67.7
1950..	9,397	474	33	110	499	222	9,073	60.4	10,714	10,390	69.2
1951..	10,190	499	51	136	549	489	9,566	63.3	11,481	10,857	71.9
1952..	10,321	549	71	154	489	392	9,906	64.6	11,527	11,112	72.4
1953..	8,971	489	164	134	327	298	8,865	56.8	10,006	9,900	63.5
1954..	8,932	327	184	105	449	278	8,611	54.1	9,870	9,549	60.0
1955..	10,027	449	175	126	421	234	9,870	60.8	10,990	10,833	66.8
1956..	10,284	421	151	138	280	229	10,209	61.8	11,200	11,125	67.3
1957..	9,579	280	144	144	194	213	9,452	56.1	10,424	10,297	61.1
1958..	9,618	194	193	118	206	192	9,489	55.4	10,454	10,325	60.2
1959..	11,131	206	186	143	264	181	10,935	62.7	11,993	11,797	67.6
1960..	10,863	264	186	138	170	183	10,822	61.0	11,605	11,564	65.2
1961..	10,730	170	187	139	200	201	10,547	58.5	11,412	11,229	62.2
1962..	11,229	200	216	132	230	210	11,073	60.5	11,841	11,685	63.9

1/ Derived from Census estimates of population eating out of civilian food supplies, unadjusted for underenumeration.

2/ Includes production and consumption from farm slaughter.

3/ Less than 500,000 pounds.

APPENDIX III
THE DYNAMIC HOG CYCLE MODEL

A.III-1 Equations

```
L       IP.K=IP.J+(DT)((MSSR.JK+OSSR.JK)(LWSH*DY)-CR.JK)
N       IP=IPN
C       IPN=200E6
C       LWSH=240
C       DY=.58
A       COV.K=IP.K/ECR
C       ECR=.99E9
A       RCOV.K=COV.K/DCOV
C       DCOV=.36
A       HP.K=TABLE(HPTAB,RCOV.K,.4,1.6,.4)
T       HPTAB=24.8/20.6/16.4/12.2
L       FEHP.K=FEHP.J+(DT)(HP.J-FEHP.J)/FEHPAD
N       FEHP=FEHPN
C       FEHPN=21.2
C       FEHPAD=6
A       EHCR.K=FEHP.K/FECP
C       FECP=1
A       DBS.K=TABLE(BSTAB,EHCR.K,10,25,5)
T       BSTAB=5E6/7E6/9E6/10.6E6
R       BSAR.KL=(DBS.K-BS.K)/BSAD
C       BSAD=5
L       BS.K=BS.J+(DT)(BSAR.JK-OSSR.JK)
N       BS=BSN
C       BSN=8.2E6
R       OSSR.KL=(BS.K*FSBS)/APLS
C       FSBS=.6
C       APLS=36
R       BR.KL=BS.K*LPHM*PSPL
C       LPHM=.17
C       PSPL=7.0
R       MR.KL=(DELAY3(BR.JK,GMD))*WSF
C       GMD=10
C       WSF=.7
L       MS.K=MS.J+(DT)(MR.JK-MSSR.JK-BSAR.JK)
N       MS=MSN
C       MSN=13E6
R       MSSR.KL=MS.K/MSFP
C       MSFP=2
A       RP.K=(HP.K/DY)+MM
C       MM=28
A       PCCP.K=TABLE(CONTAB,RP.K,40,80,20)
T       CONTAB=6.4/5/3.7
R       CR.KL=(POP)(PCCP.K)(1+INPUT.K)
C       POP=200E6
A       INPUT.K=STEP(SH,ST1)+STEP(-SH,ST2)+SAMPLE(NH*NORMRN(0,NSD),SI,0)
C       SH=0
C       ST1=3
C       ST2=12
C       NH=0
C       NSD=.5
C       SI=7
PLOT    IP=I(0,400E6)/BS=B(5E6,12E6)/CR=E(6E8,14E8)/RP=P(30,100)
SPEC    DT=.5/LENGTH=120/PRTPER=0
A       PLTPER=STEP(PP,PIT)
C       PP=4
C       PIT=0
```

A.III-2 Definitions

IP	INVENTORY OF PORK	(LBS)
IPN	INITIAL VALUE OF IP	(LBS)
LWSH	LIVE WT. OF SLAUGHTERED HOGS	(LBS)
DY	HOG DRESSING YIELD	(DIMENSNLESS)
COV	COVERAGE PROV. BY INVENTORY	(MOS)
ECR	EXPECTED CONSUMPTION RATE	(LBS/MO)
RCOV	REL COV PROV BY INVENTORY	(DIMENSNLESS)
DCOV	DES COV PROV BY INVENTORY	(MOS)
HP	LIVE HOG PRICE	($/100 LBS)
HPTAB	TABLE OF LIVE HOG PRICES	($/100 LBS)
FEHP	FARMERS' EXPECTED HOG PRICE	($/100 LBS)
FEHPN	INITIAL VALUE OF FEHP	($/100 LBS)
FEHPAD	FARMERS' EXP HP ADJ. DELAY	(MOS)
EHCR	EXPECTED HOG-CORN RATIO	(BSHL/100 LB)
FECP	FARMERS' EXPECTED CORN PRICE	($/BUSHEL)
DBS	DESIRED BREEDING STOCK	(HOGS)
BSTAB	TABLE OF BREEDING STOCK	(HOGS)
BSAR	BREEDING STOCK ACQUIS. RATE	(HOGS/MO)
BSAD	BREEDING STOCK ACQUIS. DELAY	(MOS)
BS	BREEDING STOCK	(HOGS)
BSN	INITIAL VALUE OF BS	(HOGS)
FSBS	FRACTION OF SOWS IN BS	(SOWS/HOG)
OSSR	OLD SOW SLAUGHTER RATE	(SOWS/MO)
APLS	AV. PRODUCTIVE LIFE OF SOWS	(MOS)
BR	BREEDING RATE	(HOGS/MO)
LPHM	LITTERS PER HOG-MONTH	(LIT/HOG-MO)
PSPL	PIGS SAVED PER LITTER	(PIGS/LITTER)
MR	MATURATION RATE	(HOGS/MO)
GMD	GESTATION-MATURATION DELAY	(MOS)
WSF	WEANING SURVIVAL FACTOR	(DIMENSNLESS)
MS	MATURE STOCK	(HOGS)
MSN	INITIAL VALUE OF MS	(HOGS)
MSSR	MATURE STOCK SLAUGHTER RATE	(HOGS/MO)
MSFP	MATURE STOCK FEEDING PERIOD	(MOS)
RP	RETAIL PRICE	($/100 LBS)
MM	MARKETING MARGIN	($/100 LBS)
PCCP	PER-CAPITA CONSUMPTION PORK	(LBS/MAN-MO)
CONTAB	TABLE OF CONSUMPTION	(LBS/MAN-MO)
CR	CONSUMPTION RATE	(LBS/MO)
POP	POPULATION OF CONSUMERS	(MEN)
INPUT	EXOGENOUS INPUT	(DIMENSNLESS)

APPENDIX IV

CATTLE SYSTEM PARAMETER VALUES

Each of the constants and the table functions in the Dynamic Hog Cycle Model was changed to represent the beef system. This appendix lists the values of each constant and, where appropriate, refers to a table of cattle statistics from which the value was derived by inspection. Some parameter values are not precisely correct, but the biological constants which dominate the system are easily determinable. For the remainder of the values it is sufficient to ensure that the approximate magnitude of each parameter and the correct direction of each relationship is obtained. The initial values were chosen to place the system in equilibrium. Because of the similarity of the cow system to that of hogs, the hog parameter names have been retained. The models are identical except for parameter values. Unless otherwise noted, the tables are taken from Livestock and Meat Statistics, Supplement for 1967 to Statistical Bulletin No. 333, U.S. Department of Agriculture, Washington, D.C.

Assumed Value	Reference Table
IPN = 400E6	A:V.1
LWSH = 850	A:V2 & 3
DY = .58	A:V.4
ECR = 1.854E9	A:V.5
DCOV = .216	A:V.1 & 5
HPTAB = $\frac{\text{RCOV:}0 \quad .33 \quad .67 \quad 1.0 \quad 1.33 \quad 1.67 \quad 2.0}{40 \quad 37 \quad 30 \quad 20 \quad 10 \quad 3 \quad 0}$	A:V.6 & 7
FEHPN = 20	A:V.6
FEHPAD= 24	
FECP = 1	
BSTAB = $\frac{\text{EHCR:}10 \quad 15 \quad 20 \quad 25 \quad 30}{22\text{E}6 \quad 32\text{E}6 \quad 40\text{E}6 \quad 50\text{E}6 \quad 60\text{E}6}$	A:V.6 & 7

APPENDIX IV (cont'd.)

Assumed Value	Reference Table
BSN = 40E6	A:V.7
BSAD = 24	
APLS = 30	A:V.7
LPSM = .1	
PSPL = 1	
WF = .94	A:V.7
GMD = 30	
MSN = 45.15E6	
MSFP = 12	
MM = 24	A:V.8
COWTAB = $\begin{array}{ccccc} \text{RP: } 0 & 30 & 60 & 90 & 120 \\ \hline 16 & 15 & 9 & 3 & 2 \end{array}$	A:V.5
POP = 206E6	

APPENDIX V: CATTLE STATISTICS

A:V. 1

Table 119.--Frozen and cured beef: Cold storage holdings, end of month, 48 States, 1961 to date

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds
1961...	156,392	143,888	141,505	153,960	153,471	155,370	159,736	167,248	170,635	173,327	201,478	199,987
1962...	184,182	169,441	172,130	162,947	141,347	122,651	121,876	137,512	145,398	150,314	170,619	189,351
1963...	165,562	177,134	190,130	186,704	185,059	189,508	192,752	201,301	220,057	237,431	268,050	274,335
1964...	283,455	268,449	271,156	263,405	272,348	287,456	283,561	268,650	256,957	263,317	291,325	315,441
1965...	293,083	254,776	245,280	221,860	204,706	172,337	168,004	178,559	193,512	203,230	235,185	259,668
1966...	251,639	247,937	227,946	216,899	205,773	211,911	220,493	215,821	224,699	252,853	272,643	306,558
1967...	319,364	312,523	299,936	258,641	288,007	275,656	265,122	245,149	250,302	254,931	268,246	274,675

A:V. 2

Table 86.--Cattle and calf slaughter: Number by class of slaugher, 48 States, 1961 to date

Year	Cattle					Calves				
	Commercial			Farm	Total	Commercial			Farm	Total
	Federally inspected	Other	Total 1/			Federally inspected	Other	Total 1/		
	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head
1961 ..	19,968	5,666	25,635	836	26,471	5,005	2,696	7,701	379	8,080
1962 ..	20,339	5,745	26,083	828	26,911	4,980	2,515	7,494	363	7,857
1963 ..	21,662	5,570	27,232	838	28,070	4,535	2,298	6,833	371	7,204
1964 ..	25,133	5,685	30,818	860	31,678	4,820	2,434	7,254	378	7,632
1965 ..	26,614	5,733	32,347	824	33,171	5,076	2,344	7,420	368	7,788
1966 ..	27,319	6,408	33,727 2/	444 2/	34,171	4,432	2,215	6,647 2/	214 2/	6,861
1967 ..	27,780	6,089	33,869 2/	429 2/	34,298	4,002	1,917	5,919 2/	190 2/	6,109
1968 ..										
1969 ..										
1970 ..										

1/ Total based on unrounded data.
2/ Data for 1966 and 1967 not comparable with previous years due to change in definition to include custom slaughtering in plants for farmers as part of commercial slaughter prior to 1966 custom slaughter for farmers is included as part of farm slaughter.

A:V. 3

Table 120.--Live weights of livestock slaughtered: Average per head, by class of slaughter, 48 States, 1961 to date

Year	Cattle					Calves				
	Commercial			Farm	Total	Commercial			Farm	Total
	Federally inspected	Other	Total			Federally inspected	Other	Total		
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1961..........	1,043	923	1,017	854	1,011	209	249	223	388	231
1962..........	1,027	928	1,005	853	1,001	205	257	223	384	230
1963..........	1,046	939	1,024	869	1,020	200	260	220	386	228
1964..........	1,041	929	1,020	876	1,016	204	280	230	395	238
1965..........	1,016	920	999	873	996	203	280	227	400	235
1966..........	1,031	924	1,011	872	1,009	201	304	235	394	240
1967..........	1,039	932	1,020	870	1,018	191	307	229	398	234

APPENDIX V cont.

A:V. 4

Table 148.--Dressing yields: Estimated average of slaughter under Federal inspection, 1963 to date 1/

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	CATTLE												
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1963	57.5	57.8	58.3	58.7	58.8	58.6	58.4	58.5	58.2	57.7	57.6	57.5	58.1
1964	58.2	58.7	58.5	58.6	58.7	58.5	58.3	57.5	57.5	57.1	56.7	56.8	57.9
1965	57.5	57.6	57.6	57.7	57.8	57.6	57.2	57.1	57.0	56.7	56.3	56.6	57.2
1966	57.0	57.0	57.4	57.9	57.2	58.2	58.0	57.9	58.2	58.2	57.8	58.0	57.7
1967	58.0	58.2	58.2	58.9	59.0	59.1	59.1	58.6	58.3	58.1	57.8	58.1	58.5
	CALVES AND VEALERS												
1963	56.8	57.0	56.7	56.7	56.4	57.3	57.5	57.5	56.8	56.7	56.0	56.4	56.8
1964	56.9	56.8	56.8	56.8	56.3	56.3	55.9	55.8	55.9	55.5	55.4	55.5	56.1
1965	56.0	56.1	56.3	56.1	55.7	55.7	55.8	55.7	55.7	55.4	55.4	55.6	55.8
1966	55.4	55.4	55.4	55.5	55.3	55.3	55.3	55.6	55.5	55.2	55.3	55.1	55.3
1967	55.0	55.7	55.7	55.8	55.4	55.9	56.0	55.5	55.6	55.4	55.4	55.2	55.5

A:V. 5

Tables 210 --Monthly supply and distribution of beef, veal, pork, lamb and mutton, and total meat, 1967

BEEF

Period	Commercially produced								Total 2/		
	Supply			Distribution						Civilian consumption	
							Civilian consumption				
	Produc-tion	Begin-ning stocks	Imports	Exports and ship-ments	Ending stocks	Mili-tary	Total	Per person 1/	Produc-tion	Total	Per person 1/
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Lb.	Mil. lb.	Mil. lb.	Lb.
January......	1,728	307	110	7	319	59	1,760	9.1			
February.....	1,540	319	86	9	313	58	1,565	8.1			
March........	1,693	313	92	8	300	52	1,738	9.0			
1st qtr....	4,961	307	288	24	300	169	5,063	26.2	5,062	5,119	26.2
April........	1,595	300	83	7	290	58	1,623	8.3			
May..........	1,763	290	75	7	288	68	1,765	9.1			
June.........	1,748	288	101	7	276	67	1,787	9.2			
2nd qtr....	5,106	300	259	21	276	193	5,175	26.6	5,132	5,224	26.8
July.........	1,604	276	133	7	265	50	1,691	8.7			
August.......	1,738	265	136	7	245	72	1,815	9.3			
September....	1,647	245	138	7	243	58	1,722	8.8			
3rd qtr....	4,989	276	407	21	243	180	5,228	26.8	5,009	5,274	27.0
October......	1,726	243	137	8	247	63	1,788	9.2			
November.....	1,616	247	119	7	267	41	1,667	8.5			
December.....	1,593	267	103	7	275	107	1,574	8.0			
4th qtr....	4,935	243	359	22	275	211	5,029	25.7	5,009	5,099	25.9
Year.....	19,991	307	1,313	88	275	753	20,495	105.3	20,212	20,716	105.9
	VEAL										
January......	67	11	2	3/	15	4	61	0.3			
February.....	59	15	1	1	13	4	57	.3			
March........	65	13	1	1	13	4	61	.3			
1st qtr....	191	11	4	2	13	12	179	.9	212	195	1.0
April........	57	13	1	3/	13	3	55	.3			
May..........	59	13	2	3/	12	5	57	.3			
June.........	60	12	2	1	12	6	55	.3			
2nd qtr....	176	13	5	1	12	14	167	.9	181	175	.9
July.........	59	12	1	1	11	3	57	.3			
August.......	68	11	1	1	9	5	65	.3			
September....	66	9	1	3/	9	6	61	.3			
3rd qtr....	193	12	3	2	9	14	183	.9	196	188	.9
October......	70	9	1	3/	11	4	65	.3			
November.....	64	11	1	3/	11	3	62	.3			
December.....	55	11	1	1	12	4	50	.3			
4th qtr....	189	9	3	1	12	11	177	.9	203	191	1.0
Year.....	749	11	15	6	12	51	706	3.6	792	749	3.8

APPENDIX V cont.

A:V. 6

Table 180.--Beef cattle: Average price received by farmers, per 100 pounds, 48 States, by months, 1961 to date

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Weighted average 1/
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
1961...	20.90	20.70	20.80	20.50	19.70	19.40	19.20	20.10	20.20	20.00	20.10	20.50	20.20
1962...	20.80	21.00	21.10	21.30	21.30	20.90	21.00	21.60	22.00	21.70	21.50	21.50	21.30
1963...	21.70	20.40	19.70	20.50	19.70	19.70	20.70	20.40	20.10	19.60	18.60	17.60	19.90
1964...	18.70	18.30	18.80	18.20	17.60	17.50	18.10	18.20	18.60	17.80	17.50	17.40	18.00
1965...	18.00	18.20	18.60	19.20	20.50	21.30	21.00	20.60	20.60	20.10	19.70	20.30	19.90
1966...	21.10	22.40	23.80	23.60	23.00	22.50	21.90	22.40	22.50	21.90	20.90	21.00	22.20
1967...	21.80	21.70	21.50	21.80	22.30	23.00	23.20	23.30	23.00	22.30	21.40	21.70	22.30
1968...													
1969...													

1/ Computed by weighting State weighted average prices by quantities sold.

Table 181.--Calves: Average price received by farmers, per 100 pounds, 48 States, by months, 1961 to date

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Weighted average 1/
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
1961...	23.80	24.10	24.40	24.10	23.50	23.10	22.90	23.20	23.30	23.60	23.70	24.10	23.70
1962...	24.70	25.00	25.20	25.40	25.10	24.70	24.60	24.70	25.10	25.00	24.90	25.60	25.10
1963...	25.30	24.90	24.80	25.20	24.70	24.20	24.30	24.20	23.90	23.20	22.80	22.10	24.00
1964...	22.80	23.20	23.20	22.20	21.00	19.90	19.40	19.30	19.80	19.00	19.30	19.00	20.40
1965...	20.10	20.50	20.50	21.30	21.90	23.10	22.60	22.20	22.40	22.10	22.40	23.10	22.10
1966...	24.60	26.30	27.50	26.90	26.80	26.00	25.20	26.00	26.50	25.70	25.20	25.30	26.00
1967...	25.90	26.40	26.10	26.10	26.80	26.80	27.20	26.90	26.70	26.20	25.60	25.90	26.30
1968...													
1969...													

1/ Computed by weighting State weighted average prices by quantities sold.

A:V. 7

Table 461.—Cattle and calves: Production, disposition, cash receipts, and gross income, United States, 1945–66 [1]

Year	Calf crop [2]	Death loss		Marketings [3]		Cattle shipped in for feeding and breeding [4]	Farm slaughter [5]	
		Cattle	Calves	Cattle	Calves		Cattle	Calves
	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head	1,000 head
1945	35,155	1,637	2,678	27,541	13,222	8,257	919	753
1946	34,643	1,549	2,547	26,267	13,026	8,774	943	766
1947	34,703	1,464	2,468	26,961	13,893	8,302	871	713
1948	33,125	1,388	2,247	23,417	12,607	7,595	791	611
1949	33,748	1,507	2,333	22,905	12,627	8,079	752	570
1950	34,899	1,445	2,297	22,664	12,028	8,896	713	528
1951	35,825	1,537	2,326	22,638	11,328	9,185	708	484
1952	38,273	1,603	2,431	23,652	12,246	9,091	769	494
1953	41,261	1,573	2,487	28,307	14,431	8,367	860	532
1954	42,601	1,574	2,489	30,622	15,514	9,907	872	524
1955	42,112	1,590	2,462	31,998	15,297	9,695	865	487
1956	41,376	1,487	2,425	34,155	15,578	10,609	893	487
1957	39,905	1,446	2,355	32,975	14,620	11,092	836	449
1958	38,860	1,512	2,298	31,174	13,110	12,616	813	423
1959	38,938	1,501	2,375	32,130	11,977	13,140	792	389
1960	39,355	1,567	2,533	34,254	12,034	13,477	805	390
1961	40,180	1,532	2,486	35,139	11,898	14,761	839	379
1962	41,441	1,583	2,542	36,403	12,182	16,583	831	363
1963	42,268	1,560	2,480	37,863	11,918	16,182	842	371
1964	43,809	1,595	2,637	40,280	12,552	15,595	864	378
1965	43,928	1,641	2,607	43,483	12,603	17,464	828	368
1966 [6]	43,473	1,623	2,424	45,324	12,345	18,531	445	214

A:V. 8

Farm-to-Wholesale and Wholesale-to-Retail Margins on Meat by Species, Annual Averages, 1949–62, United States [a]

YEAR	FARM-WHOLESALE MARGINS			WHOLESALE-RETAIL MARGINS		
	PORK[b]	BEEF[c]	LAMB[d]	PORK[b]	BEEF[c]	LAMB[d]
	—cents per retail pound—			—cents per retail pound—		
1949	10.7	5.3	8.6	10.4	14.9	14.2
1950	9.6	5.2	7.5	11.5	16.1	14.8
1951	9.7	5.3	6.8	13.2	17.1	14.0
1952	10.5	6.2	10.1	12.9	17.6	16.8
1953	10.1	8.0	11.0	12.4	16.9	15.7
1954	10.2	7.8	10.9	13.6	15.9	17.7
1955	11.8	8.4	10.7	13.8	16.1	17.3
1956	11.4	8.8	10.8	13.5	16.5	17.3
1957	12.0	9.2	11.2	15.0	17.8	18.5
1958	12.4	8.7	11.3	15.5	19.9	20.5
1959	12.5	9.4	11.5	17.3	20.4	21.5
1960	12.2	10.4	11.0	15.1	20.9	21.8
1961	11.0	10.3	11.1	16.8	22.6	22.3
1962[e]	11.4	8.7	[f]	16.7	21.2	[f]
			Percentage Change			
1949–50 to 1960–61	14.3	97.1	37.3	45.7	40.3	52.1

[a] *All margins are differences between prices per pound of meat sold at retail.*

[b] *Selected cuts of pork.*

[c] *U.S. Choice grade beef.*

[d] *U.S. Choice grade lamb.*

[e] *Preliminary.*

[f] *Not available.*

Source: Economic Research Service: The Marketing and Transportation Situation, *MTS-145, U.S. Dept. of Agric., May, 1962, pp. 43–48, and subsequent issues.*

APPENDIX VI

THE DYNAMIC COW CYCLE MODEL

```
*       DYNAMIC COW CYCLE MODEL
L       IP.K=IP.J+(DT)((MSSR.JK)(LWSH*DY)-CR.JK)
N       IP=IPN
C       IPN=400E6
C       LWSH=850
C       DY=.58
A       COV.K=IP.K/ECR
C       ECR=1.854E9
A       RCOV.K=COV.K/DCOV
C       DCOV=.216
A       HP.K=TABLE(HPTAB,RCOV.K,0,1.998,.333)
T       HPTAB=40/37/30/20/10/3/0
L       FEHP.K=FEHP.J+(DT)(HP.J-FEHP.J)/FEHPAD
N       FEHP=FEHPN
C       FEHPN=20
C       FEHPAD=24
A       EHCR.K=FEHP.K/FECP.K
A       FECP.K=1
C       SI=24
C       NSD=.5
C       NM=.1
A       DBS.K=TABLE(BSTAB,EHCR.K,10,30,5)
T       BSTAB=22E6/32E6/40E6/50E6/60E6
R       BSAR.KL=(DBS.K-BS.K)/BSAD
C       BSAD=24
L       BS.K=BS.J+(DT)(BSAR.JK-OSSR.JK)
N       BS=BSN
C       BSN=40E6
R       OSSR.KL=BS.K/APLS
C       APLS=30
R       BR.KL=BS.K*LPSM*PSPL
C       LPSM=.1
C       PSPL=1
R       MR.KL=(DELAY3(BR.JK,GMD))*WF
C       GMD=30
C       WF=.94
L       MS.K=MS.J+(DT)(MR.JK-MSSR.JK-BSAR.JK)
N       MS=MSN
C       MSN=45.15E6
R       MSSR.KL=MS.K/MSFP
C       MSFP=12
A       RP.K=(HP.K/DY)+MM
C       MM=24
A       PCCP.K=TABLE(CONTAB,RP.K,0,120,30)
T       CONTAB=16/15/9/3/2
R       CR.KL=(POP)(PCCP.K)
C       POP=206E6
```

BIBLIOGRAPHY

Åkerman, G., "The Cobweb Theorem: A Reconsideration", Quarterly Journal of Economics, Vol. 71, Feb. 1957, pp. 151-160.

Arrow, K. J., Social Choice and Individual Values, New York; Wiley, 1951.

Arrow, K. J., & Nerlove, M., "A Note on Expectations and Stability" Econometrica, Vol. 26, April 1958, pp. 297-305.

Ballmer, R. W., Copper Market Fluctuations: an Industrial Dynamics Study, Unpublished Masters dissertation, M.I.T., 1960.

Baranyai, L., & Mills, J. C., International Commodity Agreements, Mexico: Center of Monetary Study for Latin America, 1963.

Bean, L. H., "The Farmer's Response to Price", Journal of Farm Economics, Vol. 11, 1929, pp. 368-385.

Bjorka, "The Direct Marketings of Hogs", Bureau of Agr. Economics, Misc. Publication No. 222, March 1935.

Brandow, G. E., "Factors Associated with Numbers of Sows Farrowing in the Spring and Fall Seasons", Pa. Agr. Exp. Sta. A.E. and R.S. 7, 1956.

Breimyer, H. F., "Effects of Feed Price Stabilization Programs on Livestock", Journal of Farm Economics, Vol. 36, Nov. 1954, pp. 680-686.

Breimyer, H. F., "Observations on the Cattle Cycle", Agricultural Economics Research, Vol. 7, Jan. 1955, pp. 1-10.

Breimyer, H. F., "Emerging Phenomenon: A Cycle in Hogs", Journal of Farm Economics, Vol. 41, Nov. 1959, pp. 760-768.

Breimyer, H. F., "Demand and Prices for Meat", U. S. Dept. of Agr. Econ. Res. Ser. Tech. Bull. No. 1253, Dec. 1961.

Brenner, S., Prophecies of Future Ups and Downs in Prices , Cincinnati, 1876.

Brownlee, O. H. & Gainer, W., "Farmers' Price Anticipation and the Role of Uncertainty in Farm Planning", Journal of Farm Economics, Vol. 31, May 1949, pp. 266-275.

Buchanan, N. S., "A Reconsideration of the Cobweb Theorem", Journal of Political Economy, Vol. 47, Feb. 1939, pp. 67-81.

Burmeister, C. A., "Cycles in Cattle Numbers", The Livestock and Meat Situation, U. S. Bureau of Agricultural Economics, March 1949.

BIBLIOGRAPHY cont.

Carmichael, C. J., & Rice, J. B., "Variations in Farrow: With Special Reference to the Birth Weight of Pigs", University of Illinois Agr. Exp. Sta. Bul. No. 226, May 1920.

Carroll, W. E., Krider, J. L., & Andrews, F. N., Swine Production, New York: McGraw-Hill, 1962.

Coase, R. H., & Fowler, R. F., "Bacon Production and the Pig-cycle in Great Britain", Economica, N.S. Vol. 2, May 1935, pp. 142-167.

Coase, R. H., & Fowler, R. F., "The Pig-Cycle: A Rejoinder", Economica, N.S. Vol. 2, Nov. 1935, pp. 423-428.

Coase, R. H., & Fowler, R. F., "The Pig-Cycle in Great Britain: An Explanation", Economica, N. S. Vol. 4, Nov. 1937, pp. 55-58.

Coase, R. H., & Fowler, R. F., "The Analysis of Producers' Expectations", Economica, N. S. Vol. 7, Aug. 1940, pp. 280-292.

Cohen, K. J. & Cyert, R. M., "Computer Models in Dynamic Economics", Quarterly Journal of Economics, Vol. 75, Feb. 1961, pp. 112-127.

Cohen, R., & Barker, J. D., "The Pig Cycle: A Reply", Economica, N. S. Vol. 2, Nov. 1935, pp. 408-422.

Dean, G. W. & Heady, E. O., "Changes in Supply Response and Elasticity for Hogs", Journal of Farm Economics, Vol. 40, Nov. 1958, pp. 845-860.

Economic Research Service, Livestock and Meat Statistics, Washington, D.C.: U. S. Dept. of Agr., various issues.

Elliot, F. F., "Adjusting Hog Production to Market Demand", Univ. of Ill. Agr. Exp. Sta. Res. Bul. 253.

Ezekiel, M., "The Cobweb Theorem", Quarterly Journal of Economics, Vol. 52, Feb. 1938, pp. 255-280.

Farnsworth, H. C. & Jones, W. O., "Response of Wheat Growers to Price Changes", Economic Journal, Vol.66, June 1956, pp.271-287.

Forrester, J. W., Industrial Dynamics, Cambridge, Mass: The M.I.T. Press, 1961.

Forrester, J. W., Urban Dynamics, Cambridge, Mass: The M.I.T. Press, 1969.

French, B. C., & Bressler, R. G., "The Lemon Cycle", Journal of Farm Economics, Vol. 44, Nov. 62, pp. 1021-1036.

BIBLIOGRAPHY cont.

Goreux, L. M., "Cocoa: Simulation of Stabilization Policies", Unpublished Manuscript, Washington, D. C.: International Bank for Reconstruction and Development, February 11, 1969.

Haas, C. G., & Ezekiel, M., "Factors Affecting Hog Prices", U. S. Dept. of Agr. Bul. 1440, Nov. 1926.

Hamilton, H. R. et. al., *Systems Simulation for Regional Analysis -- An Application to River Basin Planning*, Cambridge, Mass.: The M.I.T. Press, 1969.

Hanau, A., "Die Prognose Der Schweinpreise", Sonderheft 7 & 8, Vierteljarshefte zur Konjunkturforschung, Berlin: Institut fur Konjunkturforschung, 1928 & 1930.

Harlow, A. A., "The Hog Cycle and the Cobweb Theorem", *Journal of Farm Economics*, Vol. 42, Nov. 1960, pp. 842-853.

Heady, E. O. & Kaldor, D. R., "Expectations and Errors in Forecasting Agricultural Prices", *Journal of Farm Economics*, Vol. 62, Feb. 1954, pp. 34-47.

Larson, A. B., "The Hog Cycle as Harmonic Motion", *Journal of Farm Economics*, Vol. 46, May 1964, pp. 375-386.

Lorie, J. H., "Causes of Annual Fluctuations in the Production of Livestock and Livestock Products", *Journal of Business*, Vol. 20, April 1947, Part 2.

Mac Bean, A. I., *Export Instability and Economic Development*, Cambridge, Mass.: Harvard University Press, 1966.

Maki, W. R., "Decomposition of the Beef and Pork Cycles", *Journal of Farm Economics*, Vol. 44, Aug. 62, pp. 731-743.

Mills, E. S., "The Use of Adaptive Expectations in Stability Analysis: Comment", *Quarterly Journal of Economics*, Vol. 75, May 61, pp. 330-335.

Nerlove, M., "Adaptive Expectations and Cobweb Phenomena", *Quarterly Journal of Economics*, Vol. 72, May 1958, pp. 227-240.

Nord, W. C., *Growth of a New Product: Effects of Capacity Acquisition Policies*, Cambridge, Mass.: The M.I.T. Press, 1963.

Packer, D. W., *Resource Acquisition in Corporate Growth*, Cambridge, Mass.: The M.I.T. Press, 1964.

Pugh, A. L., III, *DYNAMO User's Manual*, (2nd ed.), Cambridge, Mass.: M.I.T. Press, 1963.

BIBLIOGRAPHY cont.

Pugh, A. L., III, "DYNAMO II User's Manual", Unpublished Manuscript #D-100-2, Cambridge: Mass., Sloan School of Management, M.I.T., 1968.

Ricci, U., "Die 'Synthetische Okonomie' von Henry Ludwell Moore", Zeitschrift fur Nationalokonomie, Wien: Band 1, Heft 5, 1930, p. 656.

Roberts, E. B., The Dynamics of Research and Development, New York: Harper & Row, 1964.

Samuelson, P. A., "Dynamic Process Analysis", in Ellis, H.S. (Ed.), A Survey of Contemporary Economics, Philadelphia: American Economic Association, Blakiston Co., 1948, pp. 352-376.

Samuelson, P. A., Economics -- An Introductory Analysis, 5th. ed., New York: McGraw-Hill, 1961.

Schlager, K. J., A Systems Analysis of the Copper and Aluminum Industries: An Industrial Dynamics Study, Unpublished Masters dissertation, M.I.T., 1961.

Schultz, H., Der Sinn der Statistischen Nachfragen, Heft 10, Veroffentlichungen der Frankfurter Gesellscheft für Konjunkturforschung, Kurt Schroeder Verlag, Bonn; 1930.

Schultz, T. W., & Brownlee, O. H., "Two Trials to Determine Expectation Models Applicable to Agriculture", Quarterly Journal of Economics, Vol. 56, May 1942, pp. 487-496.

Skadberg, J. M., & Futrell, G. A., "An Economic Appraisal of Futures Trading in Livestock", Journal of Farm Economics, Vol. 48, Dec. 1966, pp. 1485-1489.

Tinbergen, J., "Bestimmung und Deutung von Angebotskurven, Ein Beispeil", Zeitschrift für National Okonomie, Wien; Band 1, Heft 5, 1930, p. 671.

Tobin, B. F., & Arthur, H. B., Dynamics of Adjustment in the Broiler Industry , Boston: Harvard University Press, 1964.

Tomek, W. G.,"Changes in Price Elasticities of Demand for Beef, Pork and Broilers", Journal of Farm Economics, Vol. 47, Aug. 1965, pp. 793-802.

Tomek, W. G., & Cochrane, W. W., "Long-Run Demand: A Concept, and Elasticity Estimates for Meats", Journal of Farm Economics, Vol. 44, Aug. 1962, pp. 717-730.

United Nations, World Economic Survey, 1958, New York; 1958.

United Nations, International Compensation for Fluctuations in Commodity Trade, New York; 1961.

United Nations, United Nations Conference on Trade and Development, Vol. III Commodity Trade, France; 1965.

BIBLIOGRAPHY cont.

Wallich, H.C., "Stabilization of Proceeds from Raw Material Exports", in Ellis, H. S. & Wallich, H. C. (eds.), Economic Development For Latin America, St. Martins, 1961, pp. 342-361.

Warren, G. F. & Pearson, F. A., The Agricultural Situation, Economic Effects of Fluctuating Prices, N.Y.; 1924.

Weymar, H., The Dynamics of the World Cocoa Market, Cambridge, Mass.: M.I.T. Press, 1969.

Williams, D. B., "Price Expectations and Reactions to Uncertainty by Farmers in Illinois", Journal of Farm Economics, Vol. 33, Feb. 1951, pp. 20-39.

Williams, W. F., and Stout, T. T., Economics of the Livestock-Meat Industry, New York: MacMillan Co, 1964.

Wright, S., "Corn and Hog Correlations", U.S. Dept. of Agricultural Bul. No. 1300, 1925.

BIOGRAPHICAL NOTE

The author, Dennis Lynn Meadows was born June 7, 1942, in Tulsa, Oklahoma, the son of Jack and Marjorie Meadows. He attended John Marshall High School in Rochester, Minnesota, and Carleton College from which he graduated magna cum laude with a B.A. in chemistry in 1964.

His work at Carleton, supported in part by a National Merit scholarship, leadto membership in Phi Beta Kappa and associate membership in Sigma Xi. In September 1964 he entered the doctoral program of the M.I.T. Sloan School of Management as a National Defense Education Act fellow. He concentrated his studies in the areas of Statistics, Management Information and Control Systems, Industrial Dynamics, and Management of Science and Technology. He was elected to Sigma Xi in 1968 and completed the Ph.D. requirements in May 1969 with submission of a thesis, The Dynamics of Commodity Production Cycles: A Dynamic Cobweb Theorem. Other papers include: "Estimate Accuracy and Project Selection Models in Industrial Research," Industrial Management Review, IX, No. 3, Spring 1968, pp. 105-119; "Characteristics and Implications of Forecasting Errors in the Selection of R&D Projects," presented at the Second Annual Technology and Management Conference, Washington, D.C., March 13, 1968; "Policy Design for Gas Reserves Acquisition Using Industrial Dynamics," with Carl Swanson, presented at the 1969 Transmission Conference of the American Gas Association, May 26, 1969; "Micro-Analytic Process Simulation: Management Tool for Technical Planning," with Leon Liebman, presented at the Conference on Technological Forecasting, June 9-13, 1968, Lake Placid, New York.

His work experience includes employment at Argonne National Laboratory as an ACM Fellow in 1963, consultant to a Development Planning Group of Bell Telephone Laboratories in 1968-69, course director for the Industrial Management Center conference series on technological forecasting methodology 1968-69, research associate of the M.I.T. Program on the Management of Science and Technology in 1965, and Instructor in management at M.I.T. in 1968-69.

His wife is Dr. Donella Hager Meadows of Prospect Heights, Illinois.