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Chapter Title: Toward a Theory of Inventory Behavior

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13. *Toward a Theory of Inventory Behavior*

In urgent need of being written, bit by bit, is the story of how flows of information take place, whereof they consist, how they influence expectations, how they are interpreted in actions, and how actions affecting income and product are translated back into information and expectations is a story.

IMPLICATIONS CONCERNING ECONOMIC CHANGE

It is, of course, a difficult story even to embark upon. For this there are several reasons. One concerns the character of the two worlds and of their relationship to one another. In a sense the two are one: information and action are, like mind and matter, part of the same corpus. Few actions do not rest on information and are not in turn converted to a "signal." But in another sense they are part of a continuum, one end of which is scraps of information and the other end of which is a concrete act. The continuum can stretch, for example, from an isolated and possibly irrelevant observation of a sentence in a trade journal to a response in terms of newly rolled steel sheet spinning onto its giant spools, or from a notation in a secret-service file that a cargo ship was sighted here, not there, to young men creeping over a beachhead. Dead center between the two ends of the continuum lies the command.

The Role of Orders

The command is identical to action if it is always precisely converted into action. Thus if new orders, which are in essence pieces of information, are never canceled and always delivered precisely as written, they are for all intents and purposes simply predated acts—shipments. In actuality, orders are sometimes canceled, postponed, or delivered late. Nevertheless the correspondence is close enough so that new orders cannot provide an explanation of shipments. They are too nearly simply an earlier version of the same thing. This is the difficulty to which I pointed in Chapter 1 when alluding to the serious deficiencies in current explanations of stocks in which orders, or changes in unfilled orders, play such a powerful causative part. In this book, orders have been cast partly in the role of effect rather than cause, since one definition of stocks includes stock on order. In a sense, then, a borderline member of the world of information, outstanding purchase orders, has been joined to the physical world of action and things.

The construct belongs fully to neither world. To picture output and income flows, ownership must be cracked apart and stock on hand alone isolated. To study the flow of information at a causal level, it is necessary to go behind the order to see what caused it. But in spite of these deficiencies, the half-breed has talents of its own—a power to display and convey information: On the one hand, ownership has a different speed of

change and process of change than has stock on hand. On the other hand, it reflects information and expectations very sensitively and in a particular sort of way. Both characteristics demand recognition in the theory of inventory cycles.

As to the speed and process of change, two different manifestations are important. For one thing, the fact that orders swiftly embody intentions means that, particularly for department stores, intentions, and therefore the theory behind action, are readily visible in ownership though obscure in stocks. This is a convenience rather than a new ingredient.

But the order, and its inherent fluidity, condition the characteristics of vertical linkages in the economy. If only shipments or stocks are examined, the transmission of fluctuation associated with sales-linked stock objectives ought, it would seem, to move backward through the economy with sequential anticipatory leads and increasing amplitudes of fluctuation. But if we concentrate on flows of information instead, notably orders, the retailers' buying and producers' buying of raw materials can be linked with the speed of light, or at worst the time required for three telephone calls. The previous chapter expanded briefly on this point. It explains, I believe, a phenomenon that has troubled students for many years—the fact that though the logic of the acceleration principle calls for progressive acceleration (in timing as well as volume) as demand moves stepwise to earlier stages, empirical evidence fails to show it.[1]

The second attribute of ownership or outstanding materials orders, that of reflecting information and experience very sensitively, involves not so much the particular stock construct as it does a way of viewing the entire problem of procurement. It elevates the world of information to a place in the analysis where it cannot for one moment be forgotten.

At the microeconomic level, emphasis on information means that, on the one hand, the notion of process is analyzed in terms of the information that the businessman uses and the expectations that he formulates. In the case of the procurement process, this emphasizes the part that expectations about market conditions can play in the timing of buying. It emphasizes possible changes in opportunity costs, including qualitative changes in customers' requirements. It emphasizes and particularizes the informational role of new sales orders.

But at a macroeconomic level, too, the emphasis on information and expectations has interesting implications which I want to develop. One reason for trying to think through some of these implications is a negative one: the speed with which information in general, and orders in particular, travel undercuts the basic assumption of "period analysis" as a complete explanation of inventory cycles. "The only indispensable assumption in the theory of the inventory cycle is that businessmen do not immediately adapt their production plan to a change in sales." [2] But insofar as orders constitute the adjustment, it can be virtually immediate. Moreover, insofar as expectations about market conditions are the reason for the adjustment, it is not unlikely that many people would want to adjust in the same way at very nearly the same time. If so, the inventory cycle could undergo a series of explosions or, if there were ceilings to response, a sawtooth rattle. There must be some way to explain the fact that time series do not show either peculiarity.

An Ecological Process

Accordingly, it may be useful to reflect on the patterns of interaction between information and action and what these interactions

[1] In lecture notes written thirty or forty years ago, Wesley C. Mitchell lingered over this problem. He explained it very tentatively in terms of inventory objectives conceived as fairly broad bands rather than as precise ratios. Many subsequent students have ignored the problem.

[2] Lloyd Metzler, "Factors Governing the Length of Inventory Cycles," *Review of Economics and Statistics*, January 1947, p. 11.

imply about the course of economic change. Biology has a word for it: "Ecology" concerns ". . . the relations between living organisms and their environment." [3] The focus seems directly applicable to economics when living organisms are restricted to man, and environment to the portion (largely though not exclusively economic) which influences economic behavior.

The way has been prepared for studies of the ecology of economic processes by the work of Herbert Simon. He has developed the notion that though man is "intendedly rational" in the sense attributed to Economic Man, the best that can actually be achieved is "satisfying," not "maximizing" or even "optimizing," behavior. Divergence from optimization is caused in part by shortcomings of available information and man's capacity to manipulate it. This implies that satisfying is at best slovenly optimizing fraught with uncertainty. But two characteristics are more fundamental in their implications: (1) Perception is necessarily selective; we appreciate, perceive, and even see not a total situation but the part of it for which we are in some sense ready. (2) That which is deemed "satisfactory," and which serves consequently as a proximate goal, changes as events prove the goal accessible or inaccessible.[4] If these two simple notions are taken seriously, and they are founded on widely held psychological ideas, the course of aggregate economic change will typically follow a different course from that implied by "optimizing" behavior.

The point of view demands an analysis that attends to the way in which a man sees, appreciates and thinks (on the basis of the information accessible to him) and the way a man acts (given his appreciations, expectations, customs, and what he wishes to achieve). Moving to an aggregative level, the analysis must attend to how the thinking and the acting of many men influence that of one another. Finally, at the aggregate level, the cross-influence must be encompassed: the influence of thinking on acting and of acting on thought, that is, on information and expectations, and particularly the assurance with which expectations are entertained. The simplest way to spell out these ideas is in terms of a model in which information and expectations, along with actual economic conditions, play their appropriate parts.

Note what these objectives and conceptions imply about the essential character of an aggregative model: it must be constructed out of pieces that display the behavior of individuals creating and responding to a situation which involves the behavior of other individuals in an economic environment. Man is a social animal; he is affected in his thinking, feeling, and acting by his perceptions of the thinking, feeling, and acting of other men. If an acting-reacting sequence gets under way, there is no reason at all to assume that individuals will react to the situation and to one another in a fashion that can be described in terms of linear aggregate behavior. Indeed, there is every reason to expect some sort of geometry of interaction, and it may "explode" or approach ceilings. However, there is no possible way to prejudge the particular aggregate function that will be found to apply, even if it were mathematically feasible to use it. The point is simply that the *coefficients* of response and feedback can themselves change as time goes on. How they will change can only be evaluated by constructing the social process in microanalytic terms. Happily, this is a job that computers are very able and willing to take on.

Not only the logic of information systems but also the empirical studies of previous chapters seem to present puzzles that invite a better explanation than the aggregative ap-

[3] *Webster's New World Dictonary of the American Language,* College Edition, 1959.

[4] Most of Herbert Simon's voluminous writings deal with these ideas at some level. But if a single reference is desired, I recommend Chapter 14 in *Models of Man, Social and Rational,* New York, 1957, "A Behavioral Model of Rational Choice." The article was reprinted from *Quarterly Journal of Economics,* February 1955.

proach readily affords. Chief among these is the phenomenon of thrust. Why does ownership of materials, for department store retailers as well as for durable goods manufacturers, appear, at an aggregate level, to build up abruptly as contraction ends and to exhibit the curious pattern of a uniform rate of change which abruptly ceases though other things continue to climb? A second minor puzzle is the character of the timing association between changes in sensitive prices and stocks or ownership; though a relationship seems present, ownership moves too late to be motivated primarily by anticipation of the rate of change in prices.

These empirical puzzles are joined by a theoretical one: The importance of expectations in governing the timing of buying and the speed with which information can be conveyed and responded to in terms of orders seem capable of causing abrupt spurts in buying followed by an equally abrupt plummet to a hand-to-mouth position. But the time series show gradual build ups and declines. Why? The models outlined in Chapter 11 left this question unanswered.

Clearly an explanation must focus on those parts of the inventory-purchase complex most sensitive to changing expectations. Since we need to supply a missing piece of the compound process of inventory fluctuation, it will be useful to use the device of a model.

It concerns the influence of market prospects. But it will be useful to focus on only one aspect of all the factors that influence positive or negative buying associated with actual or expected changes in market condition—delivery conditions, assortments, quality, materials prices. Only the last, materials prices (other things the same), will be examined. This is not by any means the most influential of the group; delivery conditions are doubtless the most important single factor. But expectations about prices have some expositional advantages. As a matter of fact, some of the other elements slip in too, in spite of stern efforts to exclude them.

AN ECOLOGICAL MODEL OF PRICE-TIMED BUYING

Price-timed buying can be a positive or a negative quantity. It is the increment or decrement to materials orders consequent to the fact that materials prices are, or have recently been, expected to change. It concerns primarily when, in view of expected change in prices, materials will be purchased which are in any event expected to be required. If we assume as a first approximation that the flow of goods into production (or, for retailers, goods shipped to consumers) is not affected by price-timed buying, then cumulated price-timed buying is price-timed ownership. Viewed the other way round, price-timed buying effectuates desired *changes* in price-timed ownership.

From the point of view of a purchaser, the more price-timed ownership that can be kept on order (rather than on hand), the better, assuming that the price is fixed at the time orders are placed and that there is no doubt whether goods will be delivered on schedule.[5] Materials on hand involve financing, insurance, and storage costs of which materials on order are free. However, uncertainty about delivery schedules may make it desirable to take delivery on some anticipatory purchases. In any event, delivery schedules seldom give perfect expression to the ideal separation of buying and shipments. For both reasons,

[5] Prices are not always fixed at the time the order is written. Steel producers have typically set prices at the time of shipment. (A break in the ranks by Wheeling Steel was reported in *The New York Times* of November 4, 1965.) Some products of the fats and oils industry have been priced in a similar way. These stipulations on the part of the seller force the buyer to, in effect, pay the full costs (storage, insurance, full risk, financing) for any price-timed buying he may wish to undertake.

stocks on hand will usually reflect some price-timed buying, often of an earlier date. Should the larger (or smaller) stocks no longer be desired, a compensating adjustment of new buying can adjust total price-timed ownership approximately to the level appropriate to the present situation. It is reasonable, therefore, to assume that the impact of price-timed buying is represented by changes in *ownership* without specifying which part of ownership—the part on hand or on order—is involved.

The model is built from three sorts of components: (1) structural characteristics of the industry and its member firms, (2) behavioral characteristics that define how actions resulting in price-timed buying are generated and governed, (3) market responses in terms of prices, delivery periods, and levels of plant and resource utilization. The only lags or leads that are admitted are those which seem to represent the time actually required for specified processes to take place.

Structural Assumptions

Two sorts of differences are resident in the structure of a firm and of an industry with respect to the potential advantage of price-timed buying. First, within any firm, potential advantage from further buying is a function of the level to which price-timed ownership has previously been extended. Second, the various firms in an industry differ with respect to their interest in—that is, in their proclivity to gain from—price-timed buying.

POTENTIAL COSTS AND BENEFITS OF PRICE-TIMED BUYING

That differences of both sorts are embedded in the normal structure of business situations can be seen by a moment's attention to the potential costs and benefits associated with price-timed buying. The benefit of price-timed buying is paying less for materials; the costs are those of carrying additional goods. It is advantageous to undertake positive price-timed buying so long as the expected increase in prices per unit, discounted for uncertainty, during a specified period of time is greater than the additions to carrying costs over the same period, other things the same. The discussion early in Chapter 10 spelled out the arithmetic of this statement. It implies that the *level* of price-timed ownership is a function of the expected *rate of change* in prices, discounted for uncertainty, other things the same.

In Chapter 10 this discussion is part of an analysis of other factors that bear on market-oriented buying and they imply that other things are not likely to remain the same. Indeed, in uncertain situations many changes tend to support one another. Thus an expected increase in replenishment period makes it advantageous to do price-timed buying on the basis of an expectation of a given price change which is less sure than would otherwise be required to justify it. The same remark applies to a change in back orders; if finished goods are sold at a price that is based on *present* costs of materials, the sale can be "covered" by materials purchases without many of the risks that would normally attend price-timed buying.[6] These thoughts re-emphasize the artificiality of a model that focuses on only one part of a process which *necessarily* moves as a whole. Since this thought is a constant irritant, let me then enter this blanket demurrer and cease bothering the reader by something that ceaselessly bothers me. Actually, as I indicate later, the model could be changed without much difficulty to cover the entire phenomenon of market-oriented purchasing. However, it can best be constructed in the first instance with the focus on price alone.

Optimum ownership associated with expec-

[6] It may be alleged that the normal procedure should be to cover, and that the notion of price-timed buying ought to apply to the failure to cover. Perhaps. But the critical point is that if prices were confidently expected to decline (and there was no problem about getting the materials later), a purchasing agent would *not* cover.

tations of change in prices is the point at which the following marginal equality is attained:

$$\text{Price-timed ownership in terms of months of expected sales} = \frac{\text{Per cent price change per month per unit}}{\text{Per cent marginal carrying costs per month per unit}}$$

In actuality, the price change in the formula is of necessity the expected change and it is, in effect, discounted for uncertainty. Carrying costs which have previously been discussed include storage, insurance, financing, physical depreciation, and obsolescence. The formula states that if, for example, the price of some material was *confidently* expected to rise 3 per cent per month, and carrying costs were confidently estimated at 18 per cent of selling price a year or 1½ per cent per month, it would be worthwhile to extend ownership by a two months' supply relative to the ownership appropriate to stationary buying prices.

As long as the expected rate of rise in prices (adjusted for uncertainty) remains the same, no further price-timed ownership (and consequently no price-timed buying) is warranted. If the expected rate declines price-timed buying turns negative as ownership declines. If the rise in prices is expected to accelerate further, the level of price-timed ownership would presumably increase. However, this statement is qualified by the first assumption, below.

Of course expectations about prices, or anything else, are virtually never sure. Accordingly, the right-hand side of the equation is reduced by an uncertainty discount. This means that price-timed ownership is always less than would be appropriate to sure expectations. An increase in assurance concerning an expected rate of rise in prices would, then, operate in about the same way as an increase in the expected rate of rise, as described in the previous paragraph. Conversely, increasing assurance about falls is equivalent to a faster drop, other things the same.

ASSUMPTION: INCREASING COST OF OWNERSHIP

As the number of weeks covered by advance purchases increases, the carrying costs of stock increase, at first gradually and eventually abruptly. I state this in the form of an assumption, though there is some empirical evidence to support it.[7]

The possibility of physical depreciation may sometimes increase with increasing ownership, but the major reason for the escalation is the risk of obsolescence. The longer ahead that requirements must be forecast, the more time there is for anticipated events to prove the forecast wrong. This is especially so in a seasonal business when an advance position crosses the months of a seasonal peak. For one thing, at the seasonal peak, advance positions cover sales for a big month rather than for a normal one. For another thing, many aspects of demand may be relatively stable within a season and changeable between seasons. The seasonal peaks therefore will often mark the point of rapidly increasing risk, which constitutes a virtual ceiling to advance commitments.

A second escalation of risk involves a guess about price itself. The longer the advance commitment, the longer prices must continue to behave at least in the anticipated fashion if the purchase is to be justified. Though errors are subject to correction by secondary negative or positive buying, it may not be feasible for the correction to be complete.

ASSUMPTION: HILL-SHAPED DISTRIBUTION OF PROCLIVITY TO GAIN

The potential advantage in shifting ownership position in line with expectations about materials prices will differ for various materials that an enterprise purchases and for the same materials in different enterprises. I would like to refer to the degree of potential advantage as the "proclivity to gain from

[7] See Franco Modigliani and F. E. Hohn, "Production Planning over Time and the Nature of the Expectation and Planning Horizon," *Econometrica,* January 1955, pp. 46–66.

price-timed buying." As mentioned at the close of Chapter 2, differences in sensitivity to any factor that influences stocks is a logical necessity if the advantage to be derived from stocks is a function of many costs and benefits of specific kinds. Though businesses share broad characteristics, they do not share precise cost structures in the sense of identical relative importance of various sorts of costs and benefits. These things depend on the particulars of management talents, customers' needs and expectations, financial resources, plant and production setup, and so on. However, it will be useful to enlarge on the specifics of these implications of the earlier analysis. What then determines the proclivity to gain from price-timed buying?

Proclivity will be affected by the potential gross gain from a correct guess about prices, the potential cost of carrying stocks, and the interest of management in the guessing game itself. In other words, it will be affected by any influence on the numerator or denominator of the equation of a few pages back, and by, in effect, the subjective utility of the calculation. Without attempting to be comprehensive, some of the more important characteristics falling in each of the three categories follow.

A high proclivity is associated with the size of the impact on profits of likely changes in prices. This depends on several business characteristics, other things the same.

1. *Volatile buying prices.* If prices change very little, a correct forecast can result at best in only small advantage.
2. *Low value-added relative to the cost of materials.* The impact on profits of guessing right about a given change in buying prices is greater when materials prices represent a large portion, and value-added a correspondingly small portion, of the value of the product.
3. *Cost of information.* If few rather than many materials are used, it becomes more worthwhile to spend time studying the probable course of prices. Other factors that influence the relative cost of information are also relevant.
4. *A high turnover of working capital.* Profitability is a function of the relation of earnings to capital and is therefore reflected in capital-earnings ratios. Therefore the significance of a given earnings-sales ratio depends on the relation of sales to capitalization. A high turnover of working capital will tend to emphasize the significance of buying at the right price, other things the same.
5. *Relation of selling prices to materials prices.* If selling prices are set for a substantial period of time, the producer may have a *period of option* as to when materials are bought. This is an invitation to consider the probable changes in prices. A rather different situation, which can likewise intensify the need for advance buying, is that in which *selling prices are highly competitive* and likely to reflect the successful anticipation of changes in materials prices on the part of a few important competitors.
6. *Other opportunities to outdo competitors' efficiency.* Sure ways of effective competition are likely to be more popular than unsure ways, and in some industries, and particularly for some businesses, efficiency in factory or sales management provides a strong competitive tool. When this tool is weak, recourse to the more risky one of price-timed buying becomes more essential to effective competition.

A high proclivity is inversely associated with the impact of carrying charges, and this depends on:

7. *The possibility of stipulating when goods are to be received independently of when they are ordered.* When this can be done with confidence, the cost of price-timed ownership is reduced by confining it largely to stock on order.
8. *Low carrying costs.* Insofar as price anticipation does eventuate in related

changes in stocks, low carrying costs reduce the impact of such changes.

9. *Predictable requirements which reduce the risk of obsolescence.* Obsolescence can take the form of goods that cannot be used at all, used only after a write-down, or used inefficiently. Durable raw materials, many simple processed materials, or standard basic goods not subject to fickle demand are relatively resistant to these dangers. The presence of firm sales orders also tends to eliminate this additional risk for other sorts of materials.

A high proclivity adheres also to particular sorts of management structure and talent:

10. *Personnel.* Good judgment about price change requires that people able to make such judgments are available and authorized to make them. This requires a management structure that recognizes, provides, and rewards this type of talent. Top management talent tends to be located in purchasing operations where the factors previously mentioned contribute to a high proclivity to gain.
11. *Management philosophy.* The personality and sentiment of top management can be sympathetic or resistant to price-timed buying to which a "speculative" onus may be attached.

The proclivity to benefit from price-timed buying is a net result of all appropriate attributes in their business setting. Proclivities will differ by type of material and in firms characterized by different management problems and structure. Thus a given proclivity can be assigned to an enterprise-commodity unit.

The frequency distribution of the proclivity to benefit from price-timed buying will depend on the joint frequency distribution of all of the attributes that make for a high (or low) proclivity. What shape is the distribution likely to have?

Consider any one of the attributes making for a relatively high proclivity to gain from price-timed buying. Some commodities in some firms in a given industry will be rich in the attribute; other commodities in the same firm or in other firms in the same industry will be poor in it; but the very rich and the very poor will usually be infrequent compared with those possessing it in moderation.

For example, materials costs can be high relative to value added (item 2 above). Thus the cost of leather for a manufacturer of popular-priced men's shoes is likely to constitute a large proportion of value added, because manufacturing operations are highly mechanized and efficiently managed. At the other end of the frequency distribution, a manufacturer of high-priced women's shoes will find materials costs buried under the very large cost of many hand operations and elaborate distribution techniques. In between (consider calf leathers only) [8] lie the bulk of companies, with more men's shoe manufacturers at the high-proclivity end and women's shoe manufacturers at the low-proclivity end, and a substantial overlap somewhere in the central portion of the range where frequencies are high.

An analogous type of distribution would apply to other of the characteristics listed. Thus, a low risk of obsolescence of purchased sole and brown side leather, featured in popular priced men's shoes, would imply a high proclivity (item 9 above); the multifinished leathers characteristic of many sorts of women's shoes would place such firms at the low end of the distribution. Again, it seems reasonable to expect some humping around the central area of the array.

If we think of each enterprise-commodity unit as having a rank position from one to ten for each characteristic, then the unit's proclivity rating would be some sort of a weighted sum of the several ratings for each character-

[8] Calf and cattle hide might be considered part of the same commodity group, whereas kid and other leathers are excluded as having quite different conditions of supply.

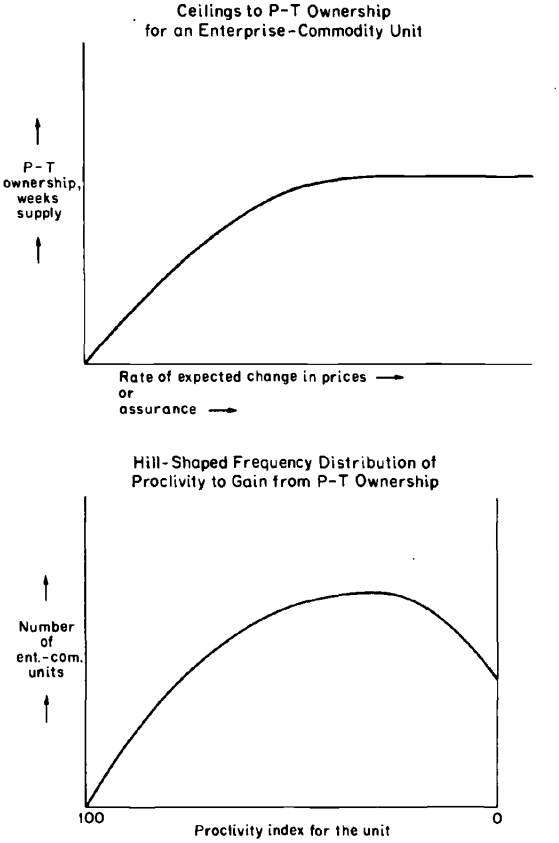
istic. The weights would represent relative importance of the characteristic in the net proclivity to gain.

Just what these distributions would look like for a given industry cannot be determined a priori. Certainly there are fewer enterprise commodity units with extremely high proclivities than with moderate ones. At some point, as proclivity ratings decline, it seems likely that the number having a given rating would typically drop off. The distribution would not be symmetrical, however, but skewed toward the low proclivity end. Critical to my argument is the basic wedge shape and the further thought that it would at least flatten. Actually it seems likely to me that it would usually decline at the low-proclivity end of the array. It seems safe to assume that these minimal requirements would be met.

In other words, for the purpose of this analysis we must abandon the notion of the "representative firm" and think instead of the hill-shaped firm, or industry, or group of industries, or economy. The representative situation is precisely not a median or some sort of *average* condition but the basic character of the *distribution* of conditions.

FIGURE 4

Potential Gain from Price-Timed Ownership



STRUCTURAL ASSUMPTIONS AND PRICE-TIMED OWNERSHIP

The essence of the two assumptions is shown in Figure 4. The top figure portrays the assumption of increasing costs and shows how, as increasing rates of change in materials prices are expected, and guesses are held with increasing assurance, the amount of price-timed ownership increases and reaches a ceiling beyond which there tends to be no inducement to adventure further. The lower figure shows the hill-shaped frequency distribution of enterprice-commodity units in an industry. Concerning the shape of the distribution, I can only say that, pending empirical study, it seems to me to be a reasonable one.

The implication of the two structural assumptions can be displayed first under the highly artificial assumption that expectations about prices are held with certainty and that there also is no uncertainty about sales or anything else capable of influencing expected costs or benefits from price-timed buying. Under these circumstances the level of ownership associated with expectations of higher and higher rates of change in prices would increase without limit and the ceilings of Figure 4 would not apply. A tabular example will illustrate the point.

Exhibit 3 assumes that the proclivities for one hundred different enterprise-commodity units range from a maximum rating of A to a minimum rating of E: the distribution of enterprise-commodity units among firms is, from A to E, 4, 22, 40, 28, 6, as shown in the top line of each of the first five columns.

EXHIBIT 3

Price-Timed Ownership and Buying, Assuming No Uncertainty,
(tons)

Expected Monthly Rate of Rise in Price	Ownership at Each Rate of Price Rise						Buying at Sequential Rates of Price Rise
	Proclivity Group					All Groups	
	A	B	C	D	E		
1/2	4					4	4
1	8	22				30	26
1 1/2	12	44	40			96	66
2	16	66	80	28		190	94
2 1/2	20	88	120	56	6	290	100
3	24	110	160	84	12	390	100
3 1/2	28	132	200	112	18	490	100

Assume further that an expected rise of the basic raw-material price of one-half of 1 per cent per month makes it worthwhile for the A group to undertake price-timed ownership sufficient to cover requirements for the sales of an additional month; for this an extra ton of materials per enterprise-commodity unit is needed. A rise of 1 per cent causes the B group to extend its ownership by a month's supply. But at that rate of price increase, the A group would extend its buying for an additional month. In each case one ton of materials is involved.

As, for each group, prices reach the rate that justifies some price-timed ownership, the amount appears in the first line of each column. But at each successive rate of rise in prices, enterprise-commodity units for which some price-timed ownership had been justified at the previous rate now should extend their position further. The appropriate levels of ownership are shown in the sequential lines for each column, that is, for each proclivity group. Aggregate ownership at each rate of price change is the sum for the five groups shown in the next-to-last column.

Additions to price-timed ownership are achieved by means of price-timed buying. This buying can be thought of as of two sorts: "initial price-timed buying," which lifts price-timed ownership from zero to the first positive figure—the difference between zero and the first lines in each column; "secondary price-timed buying," which lifts ownership to further levels appropriate to faster rates of price increase—the difference between all other lines in the table. Total price-timed buying is the sum of primary and secondary buying. It is shown in the last column of the table under the particular assumption that prices accelerated in the fashion represented by the sequential lines of the table. But of course this sequence is only one of the many patterns of change which could take place. In general price-timed buying simply effectuates the difference between the ownership appropriate to the present expected rate of change in prices and that appropriate to the previously expected rate of change. Consequently, the amount of price-timed buying at a given time depends upon the actual course of the change in prices.

This description has made a totally unrealistc assumption about the absence of uncertainty. Actually, uncertainty causes extension of ownership to involve increasing costs

EXHIBIT 4

Structural Assumptions and Price-Timed Ownership and Buying, (tons)

Expected Monthly Rate of Rise in Price	Ownership at Each Rate of Price Rise						Buying at Sequential Rates of Price Rise
	Proclivity Group					All Groups	
	A	B	C	D	E		
1/2	4.0					4.0	4.0
1	7.6	22.0				29.6	25.6
1 1/2	10.4	41.8	40.0			92.2	62.6
2	12.4	57.2	76.0	28.0		173.6	81.4
2 1/2	13.6	68.2	104.0	53.2	6.0	245.0	71.4
3	13.6	74.8	124.0	72.8	11.4	296.6	51.6
3 1/2	13.6	74.8	136.0	86.8	15.6	326.8	30.2
4	13.6	74.8	136.0	96.2	18.6	339.2	12.4
4 1/2	13.6	74.8	136.0	96.2	20.4	341.0	1.8
5	13.6	74.8	136.0	96.2	20.4	341.0	0

and decreasing benefits in line with the two structural assumptions.

To illustrate, suppose that each repetition of secondary buying for a proclivity group is associated with cutting the addition to price-timed ownership under certainty by first 10 per cent and then 20 per cent of the units—30 per cent the second time. By the third time 50 per cent is lost, and 70 per cent the fourth time. By the fifth time the ceiling has been reached for all. In Exhibit 4 the figures of Exhibit 3 are changed in accordance with this principle.[9] Now aggregate ownership itself ceases to rise after the bottom proclivity group has reached its ownership ceilings. If prices had changed in accordance with successive lines of the table, price-timed buying would be zero at that point (last column). However, it would have started to decline long before, when the decreases in secondary buying started to be larger than the increases in primary buying.

The exhibit illustrates the implications of realistic structural assumptions under entirely artificial behavioral assumptions. The latter must now be replaced by more sensible ones.

Behavioral Assumptions

The behavior on which attention centers is *price-timed buying.* By definition, it occurs in association with a change in price-timed ownership.

The amount of price-timed ownership that a firm wishes to hold depends in the first place on its position with respect to the two structural assumptions: (1) the current level of ownership—the lower the level relative to the ceiling levels, the less strong need reasons be to activate a specified amount of owner-

[9] For example, in column A, price-timed ownership under certainty, Exhibit 3, increases by four tons as the expected rate of price rise increases as shown in successive lines. Under uncertainty, Exhibit 4, we assume that four tons is cut by 10 per cent for the first round of secondary buying; thus price-timed ownership is $4 + .90 \times 4 = 7.6$. In the second round of secondary buying the increment of four is cut by 30 per cent, thus price-timed ownership is $7.6 + .70 \times 4 = 10.4$, etc.

ship; (2) the proclivity to gain from price-timed ownership—the higher the proclivity, the less strong need reasons be to activate a specified amount of ownership.

TWO LAGS

Administrative Response Lags. The placing of an order requires that an authorized purchaser make a telephone call, confirmed by an airmail letter. Authorization for routine purchases is not likely to be administratively cumbersome. It is ordinarily delegated in advance to some appropriate person. Authorization for further purchases associated with price expectations may be required to go through channels, but, in view of the presence of some leeway in most budgets, it may not actually need to wait upon confirmation. In general, then, the response lag to an increase in price-timed ownership is negligible. (Contrast this with the lag appropriate to purchases of durable capital goods.) Decreases in ownership, on the other hand, may require somewhat longer before negative price-timed buying can reduce ownership to the desired level. The maximum rate of reduction, even if there is no new buying at all, is the current volume of sales, item by item.

Learning Lag. Changes in price-timed ownership occur as a response to learning, and learning is a time consuming process. Information must be collected and inspected; it must be attended to in the sense of entering the field of perception; it must be appreciated and evaluated in terms of appropriate action.

All of these things take time and therefore give rise to a "learning lag." However, with one exception, the lag for price-timed buying is probably not long. The evidence bearing on the probable course of prices and on changes in business costs or competitors' behavior is swiftly come by. Appreciation and evaluation tend to focus on the purchasing agent's office and thus do not involve cumbersome interpersonal procedures. The exception to the potentially short learning lag lies in the process whereby assurance develops. This involves what may be thought of as a depth dimension for each of the components of learning mentioned in the previous paragraph, with particular emphasis on the last group. My point is that uncertainty must affect the learning process as well as being reflected in a final evaluation such as I discuss in the next two sections. Insofar as it does affect the learning process, it will tend to draw it out.

PRICE EXPECTATIONS AND CHANGES IN COSTS

The reason for and focus of price-timed buying is, of course, a belief about the future course of prices. The basic character of a belief about prices can be interpreted as a series of possible rates of change with likelihoods associated with each hypothetical occurrence. The complete array can be expressed in terms of an average value. Statistical decision theory formulates the average, the "expected value," as the average of all possible values weighted by their subjectively assigned probability of occurrence. But there are a number of other methods of selecting a central value.[10] Actually, most people probably deal with the future without any such mental gymnastics. Perhaps they consider, as Shackle has claimed, only two values, "focus gain" and "focus loss." [11] Perhaps they make a best guess and think also about how likely it is to turn out right. Perhaps the best guess takes

[10] For a classic formulation of statistical decision, see L. J. Savage, *The Foundations of Statistics,* New York, 1954. An excellent short summary of other decision rules is given in Irwin D. Bross, *Design for Decision,* New York, 1953, pp. 102–117.

[11] The notion is presented in *Expectation in Economics,* by G. L. S. Shackle, 2nd ed., Cambridge, 1952. An excellent short statement by Shackle appears in *Uncertainty and Business Decisions,* edited by C. F. Carter, G. P. Meredith, and G. L. S. Shackle, 2nd ed., Liverpool, 1957, pp. 94–104; see also G. Patrick Meredith, pp. 38–41, and the frontispiece, the three-dimensional diagram of the "model of the Shackle function."

the form simply of "Will prices rise, fall, or do neither?" No doubt different people think in different ways and even at different times.

The advantage associated with price-timed ownership also depends on carrying costs. Thus the amount that is undertaken will be influenced by changes which affect these costs. Previous chapters have pointed to the impact of the volume of back orders or *de facto* financing costs. What competitors are doing likewise influences the need to take a position. For one thing, it is often thought important to "buy along with the trade," since it is more dangerous to be short if competitors are long in supplies and less dangerous to take a long position (expecting prices to rise) if competitors also are long.

ASSURANCE

We have been speaking of expectations about changes in prices and costs. Expectations are hardly ever single-valued. An expected event may happen or not happen; more usually it may happen in one of many ways. Assume, to illustrate, that "expectations" take the form of a probability distribution. Thus, a purchasing agent may believe, explicitly or subconsciously, that there are 2 chances out of 10 that prices will fall, 3 that they will stay the same, and 5 that they will rise. Accordingly he believes, with some lack of conviction, that prices will rise. His assurance in this expectation would increase were his probability weights to shift to, say, 1, 2 and 7. He would feel more justified in buying more materials ahead when the distribution of weights has humped in this fashion than when it was flatter.

Or consider an example involving more specific expectations. Suppose that a purchaser thinks that five values for percentage change in prices are possible—minus 1, 0, plus .5, plus 1, plus 2. Say that if he feels relatively sure about his evaluations, they carry for him the probability ratios of .05, .10, .70, .10, .05, respectively. Then the "expected value" is plus .5 per cent change.[12] But if he feels unsure, the probability ratios might be more like .40, 0, .20, 0, .40. The "expected value" is still plus .5, but the utility of price-timed buying, and therefore the amount that will be undertaken, is likely to have been reduced by the consciousness that there are four chances out of ten that the price will go down, not up.

However, it would seem that assurance, and consequently the action to which the opinion gives rise, can also increase as a result of changes of a somewhat different sort. Since these further processes are likely to have a significant bearing on how assurance waxes and wanes in an interrelated market, I want to describe them. Unfortunately, the matter has not been much explored and is controversial, and therefore the argument must be developed at some length. However, it is entirely possible to follow the model I present by interpreting change in assurance in the conventional fashion, simply as flattening or humping of a probability distribution—and skipping or rejecting the argument concerning "assurance" which follows. It concerns four additional ways in which the impact of assurance can be conceptualized.

First there is what William Fellner has called "slanting," or Donald Ellsberg "ambiguity."[13] The notion postulates that, feeling

[12] The calculation of expected value (e.v.) is:

Expected price change, per cent	−1.0	0	+.5	+1.0	+2.0	Sum
Probability weights	.05	.10	.70	.10	.05	1.0
Prices, weighted (line 1 × 2)	−.05	0	+.35	+.10	+.10	+.5

[13] William Fellner, "Distortion of Subjective Probabilities as a Reaction to Uncertainty," *Quarterly Journal of Economics,* November 1961, pp. 670–690, and Donald Ellsberg in the same volume. Fellner describes the correction factor for uncertainty in these terms, "Instead of postulating that individuals maximize the mathematical expectation of utility it is, at least for some processes, based on psychological weights that are in the nature of *distorted* probabilities" (p. 676). He has developed this basic idea in a recent book,

unsure of the evidence, perhaps even of the relevance of the evidence, the decision maker is aware that his opinion is poorly founded and unstable. This sort of feeling is not entirely captured in a flattening in a probability distribution for it also involves a fuzziness about the whole matter. Presumably, he will put fewer chips on a fuzzy and, admittedly, potentially unsound judgment than on a better one.

A second way of thinking about the impact of assurance on action is based on the psychology of perception. People do not simply know something or not know it. Nor do they believe things the first time they hear them; if they did, life would be all crisis. Perception is a process which develops slowly. Ideas burrow into the "psychological field." As they burrow, they must in a sense pass tests of harmony with other information. They gain significance and the power to throw their weight around and influence actions. So conceived, increased assurance is a form of a more advanced degree of perception.

A third way of thinking about the capacity of price expectations to influence behavior is to let oneself slip off the polished back of the *ceteris paribus* notion. Actually, as I continue to complain, it is exceedingly difficult to cling rigorously to this basic method of scientific thought in a context where the causal process under examination necessarily *links* changes in independent variables in the system with changes in some of the elements confined within this *ceteris paribus* compound. In the context of price-timed buying, it is most unusual for prices to change without corresponding changes in quality, delivery periods, and the like. Indeed, such changes can readily be converted to a price dimension. Changes in these other market phenomena are sure to influence the subjective assignment of weight to possible price changes. They will, in other words, affect the assurance with which the price guess is made.

Finally, "expected values" or "best guesses" are often poor summaries for a probability distribution of expected values in the context of price-timed buying. They fail to take account of the differential utility of each possible price. The weighting system equates the utilities to the amount of price change, whereas actually they are often asymmetrical. Failure to anticipate a price rise means that goods have been bought at too high a price. But price-timed buying when prices fall means not only that the goods are bought at too high a price but also, in many cases, that less than optimal articles were purchased. In effect, then, the denominator of the right-hand side of the equation is, for price-timed ownership, inversely correlated with the numerator; risk of obsolescence (in the denominator) ought not to be set down at its average value but at values specifically related to specific values of the numerator, the expected rate of change in price. A further asymmetry in the utility of positive and negative error may occur at a personal level. If prices fall, a purchasing agent may be subject to criticism for advance buying to which he will not be subject for "missing the boat" if prices rise. Virtue's veil clothes the indiscretion of the resistant gambler but the mistaken gambler is fully exposed.

I conclude that whether one thinks of the "expected value" or "best guess" about prices

Probability and Profit, Homewood, Ill., 1965. Donald Ellsberg discusses "ambiguity" and takes it into account as a discount for uncertainty in the form of an index. He points out that actions may frequently favor "those definable" as "status quo" or "present behavior" since for these the degree of confidence may be high and the range of probabilities narrow.

Price theory has long introduced the notion of a discount for uncertainty. Oscar Lange described it as "*effective* expected prices." "This is the most probable price minus the risk premium. For sellers the risk premium is positive, for buyers it is negative" (p. 31). Oscar Lange, *Price Flexibility and Employment,* Bloomington, Ind., 1944. These notions could be interpreted as simply resulting from the introduction of a probability distribution rather than a single-valued expectation. However, the fact that the direction of discount is different for buyers than for sellers tends to bring the ideas into closer relation to the slanting or ambiguity notion discussed in the previous paragraph.

as influenced by "slanting," the process of perception, inevitably associated market phenomena, or asymmetry of rewards and penalties, conclusions about behavior are the same; a best guess about price change will be associated with varying amounts of price-timed ownership as assurance or confidence in it, variously defined, grows or wanes.

The Ownership Surface

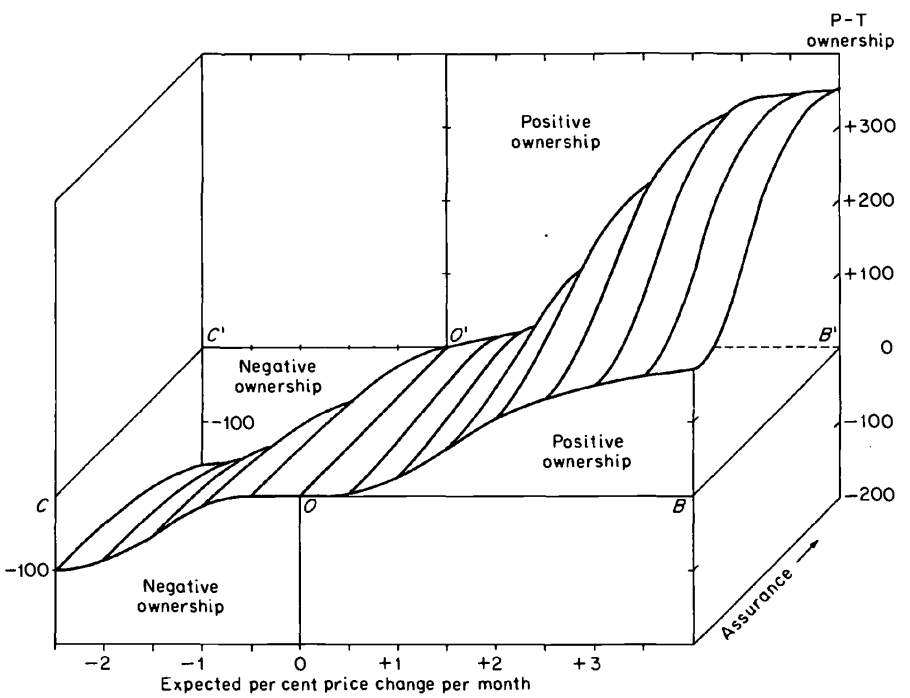
These behavioral characteristics prescribe that the levels of ownership implied by the structural assumptions must be viewed in the light of uncertainty about price expectations. The levels appropriate to sure price expectations, as illustrated in Exhibit 4, become the *limits* which would be appropriate as assurance builds up. They are shown along the back wall of an ownership surface in Figure 5.

Actually, price expectations are typically more or less unsure. Moreover, the structural as well as behavioral characteristics imply that many other aspects of the judgment of net advantage are also more or less unsure—those concerning future sales and various elements of holding costs. These judgments and those about prices are interrelated. On any or all of these counts, then, low assurance reduces the amount of price-timed ownership undertaken at each expected rate of price change. Assurance is lowest at the front wall of the surface.

The diagram should be thought of as representing potential ownership for a major material, a commodity, in an industry. Thus the CC'BB' rectangle represents zero price-timed ownership. Only such stocks as are needed for servicing sales and similar matters are held. Positive price-timed ownership is

FIGURE 5

Demand Surface for Price-Timed Ownership Sensitivity



above the plane and negative ownership below it. If no price change is expected (center of the plane along the lines OO′), there is, of course, no P-T ownership. The rate at which prices are expected to rise are shown to the right, and to fall, to the left of the OO′ line. The higher the expected rate of increase, the more enterprise-commodity units may be involved in positive ownership, and the larger the extent of their involvement. That is, the surface rises as it moves to the right because of *both* additional units starting primary buying and continued secondary buying.

When the expected rate of rise is very low and also uncertain (front wall just to the right of O), no P-T ownership is indicated even for firms having a very high proclivity to benefit from price-timed buying. As we move to the right, the diagram suggests increasing rates of rise. But actually, it is doubtful that an expected rate has much meaning when opinion is very unsure. There are perhaps a series of overlapping probability distributions that are all so flat that their meaning is little more than "prices will probably rise"; how much they are expected to rise is hard to say except that at the right it is more than toward the center. That is why the surface is relatively flat at the front wall.

The backward dimension of the diagram depicts increasing assurance. It portrays the gradual accretion of price-timed ownership associated with more enterprise units for which additions to ownership appear justified, and more ownership for each participant. As depicted, the backward dimension accounts for much of the rise in price-trend ownership. This implies that decisions concerning desired ownership are strongly affected by degrees of belief. The previous discussion has attributed the impact of assurance to the changes in the shape of the probability distribution of possible prices, and to the further forms that increased confidence can take. The form of a more "advanced degree of perception" seems to assume particular importance as one thinks of the competition for executive attention among the wide variety of things that, minute by minute, take place in a business.

Negative price-timed ownership is a response to an expected fall in price. It is illustrated in the left lower section of the diagram. The structure is highly conjectural, but is based on the supposition that the minimum true hand-to-mouth position which would presumably be appropriate if serious price decline is expected is much nearer the normal efficiency levels for ownership than is the maximum extended position. For this reason the surface never falls much below −150 (back left corner), though it rises by over +300 (back right corner). Also, the difference between behavior under uncertainty and under certainty is less extreme.

Positive price-timed buying occurs when an enterprise-commodity unit wishes to move from a lower to a higher level of price-timed ownership, or from a larger to a smaller negative level of ownership. It occurs, in other words, when there is a wish to move upward on the ownership surface. A downward movement involves negative price-timed buying. Does this buying itself influence the markets in which it takes place?

Market Response

The analysis of market response needs to be formulated largely in terms of price-timed buying rather than ownership. Price-timed buying constitutes an addition to, and negative price-timed buying a subtraction from, such buying as would occur for other than price-oriented reasons. The greater or smaller buying influences demand-supply relationships; it generates other sorts of behavior in the contacts of buyers and sellers; it influences the information that is generated in the market place. It therefore influences expectations about how prices will change in the future. The model must make some pre-

sumptions about the character of the several market responses, and these need to be specified.

Market responses are of three sorts. None of the responses are immediate. They all take time, and how much time is a function of the things that need to occur. The several responses, each involving characteristic lags, concern market behavior, information and expectations, and income generation.

MARKET BEHAVIOR AND THE MARKET-BEHAVIOR LAG

Market behavior affects price, market conditions and levels of utilization.

Price Effect. Materials prices tend to respond to price-timed buying and the strength of the response is a function of the amount of buying, other things the same. Diagrammatically, positive price-timed buying represents a short-term *shift* of a demand schedule upward and to the right. Supply schedules may also shift upward and to the left as suppliers respond to the eagerness of buyers and perhaps also to some short-term rigidities in their own production scheduling. Negative buying causes shifts in the opposite direction. Thus, in terms of the usual demand-supply-price diagrams, a flock of small new short-term schedules for demand and supply are born and intersect at higher levels of the vertical price plane.

Effect on Other Market Conditions. Other conditions in materials markets also respond to the extra demand caused by price-timed buying. The amount of the response depends in part on the amount of the buying and on its rate of change. Thus the speed and reliability of deliveries may deteriorate simply because of short-term resistance to *changing* the level of output. This means that when once output has achieved a new level, the resistance will subside.

The character of market responses has two interesting implications. First, it seems clear that at this level it is not possible to isolate the impact of price-timed buying from that of all other market influences. Second, the lag associated with these aspects of market behavior could be very short indeed. Its length would depend largely on the institutions of purchase and sale. The action-reaction pattern of an open market are almost immediate. For individually negotiated deals, substantial time may be required before additional selling or buying is reflected in market conditions, including prices. Seasonal factors can be important. Sometimes it is conventional for prices to be changed only at certain times during the year, and a growing tendency for prices to rise or fall must wait for the appropriate months. If prices are going to be raised when the line is announced, some customers may be given an opportunity to stock up earlier at the old prices; this underscores the periodic influence. The annual trade association meetings may be the battleground for a campaign to change prices.

The Level of Utilization. All these market responses will tend to be more severe when the level of utilization is high than when it is low. This observation implies a further interdependency of factors affecting ownership. Market responses to price-timed buying or to buying associated with other market expectations cannot be disentangled from responses to the broader picture of supply-and-demand conditions. If so, lags may be introduced which can be far longer than any thus far considered. They involve cyclical rhythms of intensification of the shorter market-oriented responses.

EXPECTATIONS MULTIPLIER AND THE EVIDENCE LAG

Market responses carry information which is used by prospective buyers and sellers as a basis of judging the future course of prices. Consequently, the responses have potential multiplier effects via their role as evidence and the power of information to influence expectations.

Here again, the process takes time and therefore operates with a lag. Open-market prices are widely displayed daily if not faster. On the other hand, individual contracts between producers and buyers are often secretly negotiated, and the information may be slow to leak out, if indeed it ever does. The amount of buying being done by market leaders, the condition of inventories and order books of customers and of competitors, all constitute information which may take days if not weeks to become generally known.

However the point that I want to emphasize is simply that the actions listed as market behavior all convey information. This information, after it has had time to disseminate, influences expectations the next time around. The "feedback" thus consists not only of market actions and consequent changes in demand-supply relations but also of information which, along with behavior, influences further expectations with multiplier effects.

INCOME MULTIPLIER AND THE INCOME LAG

When price-timed buying causes output to be different from what it otherwise would be, the resultant income flows are subject to the usual multiplier effects. Because the situation can change rapidly, payroll and other adjustable income flows are doubtless primarily involved. Also, the short-term level of the propensity to consume, which, of course, varies widely, will affect the extent that positive or negative price-oriented demand is amplified. Expectations may also come into play to augment or mute the income multiplier effect. The lags associated with income multipliers have been widely discussed in the literature.

The Process of Change

The gadgetry of the model of price-timed buying has now been described in terms of a group of structural, behavioral, and market characteristics which interact after several short delays.

Aggregate change results from the shifting weights to be assigned to situations described in Figure 5. The weights indicate the number of enterprise-commodity units whose price-timed ownership is at some particular place in the ownership surface and about to shift to some other place. *The shifts take the form of positive or negative price-timed buying —movements upward or downward respectively in the vertical dimension.* Systematic shifts in the pattern of weights will occur as a result of forces set in motion by an initial dose of price-timed buying and the business environment in which it takes place. What is the pattern through time of the resultant buying?

It would be satisfying to be able to answer this question by a process table that spelled out the action, feedback, decision, action pattern; but the possibility of this tidy demonstration is barred by the basic construction. The result of the aggregate level is contingent on the character of the distribution within the aggregate of proclivity, impulse, feedback sets. Moreover, it is proper to stipulate these occurrences only in terms of probabilities, not as things that will happen. The magnitude of response will therefore depend on how sequences unfold. If so, the aggregate of occurrences this month has no prescribed single relationship to selected present conditions and the aggregate of occurrences last month or the month before.

Nevertheless, though statements must remain qualitative, reasonable and realistic assumptions about objectives, information, procedures, choices, and reactions seem to lead to the conclusion that, inherently, a spaced wave of price-timed buying will be generated unless intercepted by elements external to the model. Specifically: (1) cumulation is gradual and progressive—more buying is touched off per month as the situation matures than when it is young; (2) cumulation takes time; (3) reversal is inherent.

I want to discuss the processes of cumulation and reversal without admitting factors

external to the model. Needless to say, they are present and important, especially in connection with the process of expansion.

CUMULATING EXPANSION

The course of a wave in price-timed buying of materials can be interpreted in terms of how and why enterprise-commodity units move from one position on the diagram to another. Start at a point where there is no longer a general belief that prices will fall and accordingly the desire for negative price-timed ownership has abated. This implies that positive price-timed buying has moved many firms from the lower left quadrant of the ownership surface to somewhere in the neighborhood of the origin, zero in Figure 5. I see no reason why price-timed buying in isolation could not cease at this point at which ownership tends to be at efficient levels, assuming that prices would remain stable. But I would like to suppose that there have been signs of renewed demand and other healthy underpinnings that lead to optimistic expectations.

Some firms in the industry, then, expect rises in prices, others declines. Most are unsure. There now occurs a moderate desire for price-timed ownership on the part of some firms with a high proclivity to gain. Price-timed buying would be governed by the difference between the previous and present ownership objective of the participating units.

Assume, now, that nothing from the outside occurs to counteract the effects of this initial dose of price-timed buying. Then market responses theoretically bring about a feedback: in minute quantities they would consist of behavior responses, expectation and evidence responses, and even an income multiplier.

However it seems clear that in reality there must be some threshold level below which feedback effects do not develop. How the threshold should be defined and how it operates need to be studied. It seems likely that the rate of change in final demand will be one part of the story; the sensitivity of information systems and vulnerability to competitive behavior will be another.

The initial dose, and the feedback effects, can influence expectations in four ways, and actions in one further way: (1) fewer enterprise-commodity units will be subject to the expectation of falling prices; (2) more firms may expect a rise in prices of more materials; (3) the expected rate of increase may rise, though this may well tend to be a later manifestation; (4) expectations will gain in sureness. In terms of Figure 5, concentration of situations moves to the right and especially back. Price-timed buying is positive and there is more of it than at the time of the original dose.

As time goes on, there is a fifth way in which the situation matures. It involves the objective facts with which firms are faced; the need for defensive action increases. For example, competitors may be amassing low-priced inventories or suppliers working overtime. Consequently, the *action* based on a given set of expectations, held with a given degree of assurance, increases. Diagrammatically, the surface as a whole rises. The further buying will have its own round of feedback and multiplier effects, which in turn have further influences on new expectations.

All this takes time. It takes time for businessmen to perceive developments and learn their implications. The growth of assurance is particularly deliberate, since it waits on successive confirmations of expectations and events that deepen perceptions. After decisions are formed, administrative response, though swift, is not instantaneous. It takes time for market conditions, including prices, to reflect the impact of new buying. It takes time for the evidence to be displayed, perceived, and learned to the extent necessary to influence new expectations and the assurance with which they are held.

Will a snowballing process get under way, or will countervailing forces prevail? Countervailing forces internally generated consist of (1) reduction in initial buying because the

hump of the frequency distribution of proclivities has been passed; (2) reduction in secondary buying because many units approach the long end of their long-short market range; (3) negative (or zero) price-timed buying to correct ownership based on disappointed expectations about price change. Numbers 1 and 2 will not generally occur at the early stage of movement having the basic time-consuming characteristics that I have described. Number 3, disappointed expectations, is quite another matter, for its prevalence depends on whether the stimulation to prices associated with price-timed buying is *large enough to cause prices to increase as much as or more than expected.* Is this likely to occur?

The answer hinges, I think, on whether additional buying is contingent primarily on the expectation that the price rise will accelerate (movement to the right of the diagram), or on the increasing assurance that prices will continue to rise (movement in the backward dimension). If the former governs, the situation is self-reinforcing only so long as expectation-activated buying (along with its ramifying effects) has a large enough impact on prices to validate the expectation. This implies that the price rise is at least seen to *accelerate*—a stringent requirement unlikely to be met. Moreover, the time series showed that market-oriented ownership did not parallel the rate of change in prices (nor did change in ownership, hypothetically buying, parallel the change in the rate of change).

But this hypersensitivity is not likely to be present if the growth of assurance were the chief determinant. Assurance would increase as expectations are repeatedly confirmed. If expectations attended primarily to the direction of change in prices, confirmation consists of continued change in the *same direction.* The time series showed the implied association between market-oriented ownership and prices proper (or change in ownership and change in prices).

The process, then, compounds in the five ways previously mentioned and desired ownership moves backward and somewhat to the right over the surface of the diagram. Feedback mechanisms provide a sixth mechanism which, along with the fifth, causes the surface itself to lift as the objective situation changes. This implies cumulation of a progressive sort. What brings it to a halt?

DOWNTURN AND REVERSAL

A *downturn* in price-timed buying occurs after the amount of positive buying reaches its peak. This definition parallels the usual idea of a peak in any economic activity. Note that even after a downturn, so defined, many terms might still be moving upward on the upper right segment of the ownership surface, but aggregate movement in the vertical direction would have started to decrease. If price-timed buying is visualized as superimposed on an upward phase of final buying, the downturn in price-timed buying marks the point at which its impact on total buying starts to lessen.

But for some purposes the more significant change in price-timed buying is the point at which it turns from positive to negative. At this point the influence of the timing of buying starts to depress rather than to stimulate total buying. Call this point *reversal,* admittedly in this special sense. It will be useful to note how both downturn and reversal in price-timed buying occur as a result of elements internal to the model.

Structural characteristics require that price-timed buying must turn down soon after participation in it has reached its maximum. That it does reach a maximum is guaranteed by the hill-shaped form of the proclivity to benefit and by the ceilings to price-timed ownership. Structural characteristics do not imply that reversal must set in; they imply that price-timed buying cease but not that it turn negative.

Behavioral characteristics, on the other hand, can account for both downturn and re-

versal. Insofar as expectations about rates of rise in prices determine buying, a downturn would occur when the rate of rise in the rate of rise ceased accelerating; reversal would occur when it started to decline. Although, as previously explained, formulations of this sort seem totally unrealistic, it is possible that attention to rates of change becomes more common when a buying wave has lasted long enough for assurance about the direction of change to grow strong. If so, vulnerability to reversal, as well as to downturn, increases sharply at that time.

Insofar as the increasing assurance with which expectations are held constitutes a major aspect of the developing situation, a downturn occurs, other things the same, when the rate at which assurance (more specifically the action that it motivates) is building up starts to slacken; reversal occurs when assurance begins to lessen. And it seems likely that this lessening can take place as a result of the level of activity alone. At times, for example, factors directly associated with price increases of the past will raise doubt about their continuation in the future. For one thing, if prices reach levels that are high with respect to previous levels, this fact can raise doubt whether they will continue to rise. For another thing, operating margins may narrow after prices have risen for a while; a tendency of this sort is promoted by the fact that crude products respond more sensitively to changes in demand than do finished products. Narrowing margins often raise doubts whether prices will continue to rise. Structural and behavioral characteristics, then, guarantee a downturn and virtually guarantee a reversal in price-timed buying.

But in any event market response must, it would seem, convert downturn into reversal. The presumption rests on the supposition that the strength of the reaction of prices, delivery periods, or other market phenomena are a function of the amount of price-timed buying and perhaps also of its rate of change. Sensitivity to the latter would reflect, among other things, the difficulties that suppliers experience in changing production schedules. But within a wide range of functional relationships it would necessarily be true that the amount of market response declines when the amount of price-timed buying does. If so, the information feedback signals reductions in rates of price increase and less sureness that some prices will continue to rise. If expected rates of rise occur, or the assurance with which the expectation of some threshold rate is held declines, the ownership position that is justified is reduced. In effect, enterprise commodity units shift toward the front and left of the ownership surface and negative price-timed buying effectuates the shift. Market responses to these reductions further reinforce the messages that convey doubt about further rise. Aggregate price-timed buying turns negative, that is, reversal occurs, when the amount of negative buying exceeds that of positive price-timed buying, that is, when the sum of the vertical distance by which some enterprise commodity-units drop on the ownership surface exceeds that by which others rise.

DECLINE

The negative phase of a buying wave starts while most price-timed ownership is positive, but firms are trying to reduce their position by refraining from buying. Aggregate materials procurement is therefore less than the amount required to provide for final demand. However negative price-timed buying for any firm cannot be greater than the volume of orders that would otherwise be placed to meet final demand.

It seems likely that firms that had previously engaged in positive buying would try to unload in unison. Since there is a cost attached to positive price-timed ownership, uncertainty alone may be sufficient reason to forgo the possible benefit and engage in negative buying. Uncertainty may be more contagious in a business community than is the expectation of either a rise or fall. In terms

of Figure 5, when uncertainty takes hold of industry opinion, there is a scramble of units to hop from wherever they are on the right-hand segment of the surface to somewhere on the left-hand side. Thus, though the slope of negative *ownership* is mild, negative *buying,* to effectuate downward shifts in desired ownership, can be relatively extreme.

The upturn in price-timed buying occurs as the number of firms, and the amount of the reductions desired, start to decline. Here, as for the upward peak, structural assumptions imply that the force of negative buying must decline. Indeed, the minimum hand to mouth position is doubtless far closer to the efficient service level of ownership than is the ceiling level; consequently declines must bottom off sooner.

Reversal, the start of positive buying, is brought on by the behavioral and market reaction aspects of the model in a manner generally parallel to the upper turn. However, as mentioned at the outset of this section, it seems likely that support from elements outside of the model—elements associated with final demand and other marked forces—are essential to launch price-timed buying on a climb over the positive sector of the ownership surface. However, if the support is present, the ground has been prepared for rapid and cumulating response. The decline of negative price-timed buying has already reduced the depressant influence on total buying of market oriented elements, and firms whose business has improved unexpectedly will be caught short and behave accordingly. Their behavior echoes in a manner previously described.

PRICE-TIMED BUYING AND THE INVENTORY CYCLE

A wave in price-timed buying has been described in terms of factors capable of producing self-reversing fluctuations of endogenously determined duration. It is shaped by the ecological process whereby opinion is formed, acted upon, diffused through the economy, and affected by it.

All Market-Oriented Buying

The model has focused on one aspect of market conditions—prices. Even so, changes in other aspects which are inevitably associated with changes in price—delivery period, assortments, quality—were recognized in discussions of market response to price-timed buying.

To admit these influences explicitly as part of the process embodied in a model would require, I believe, virtually no change in its basic structure. Indeed, the surface labeled price-timed ownership as shown in Figure 5 may well be a more realistic picture of market-oriented ownership than of expectation focused on price alone. The rise in expected rates of change in prices, measured along the horizontal axis, might well not actually occur unless the increase in expected costs represented by market prices were joined by costs associated with poorer selections or longer delivery terms. Likewise, the rising assurance diagrammed in the backward dimension could be caused by combinations of things that are likely to occur. For example, if, with a given degree of assurance, prices are expected to rise *and* delivery periods are expected to lengthen, there is far less to be risked by increasing ownership than if either were expected to occur without the other.

This implies that the model as described could doubtless be applied to the totality of market prospects without fundamental change.

Interindustry Diffusion

The ecology of a wave of market-oriented buying in a single industry may well also

apply across industry lines. How this can and does occur needs study, but a few guesses may be in order. For one thing, the industries in a single vertical sequence are linked in many ways. Changes in the prices of raw materials such as cotton, hides, fats and oils, and scrap metals are known and watched by firms at later stages of an industry as indicators of prices and other market conditions in the more finished lines such as cloth, shoes, shortening, autos, cooking ware, and electrical apparatus. From the finished end, the influence of final demand has a significant bearing on raw materials as well as on finished goods markets. Between the two ends of a sequence the similar expectations are promoted by the hourly and daily contacts of buyer and seller over the telephone, in the office, and in the market; each firm is both buyer of materials and seller of a product, and thus a link in a vertical chain.[14] The link is specific in connection with unfilled orders. For a particular company, undelivered sales orders on the books can, of course, take a substantial part of the gamble out of price-timed buying of materials.

The closer are business ties, the more surely will diffusion occur, and the more promptly. Consequently, it is not difficult to visualize how a buying wave can develop within a single industry sequence. But were expectations contained within these narrow channels, waves in various industries could counteract one another. If so, the quantitative impact on the economy as a whole would be small and the multiplier effects would be virtually nonexistent. Of great interest, therefore, are the factors capable of diffusing a disturbance across industry lines.

One can only guess what these are, since the subject has not been studied. The hints of parallelism that we have observed in markets so diverse as department store merchandising and durable goods manufacturing whet the curiosity to know more. One obvious carrier of diffusion is the level of final demand and its rate of change, since most commodities share in some degree the fortunes of the economy as a whole. Another candidate is the price of sensitive commodities not subject to strong independent variations in supply; for such commodities parallel price movements often occur. Here again, prices are one aspect of a more complicated set of market conditions, the influence of which spreads. It may also be that prices and market conditions in some commodities (steel is a good example) have a pervasive influence on a wide variety of other raw metals and finished goods. Other common influences—credit conditions, labor conditions, special situations of broad importance (national and international)—are likewise capable of some across the board influence on market expectations.

[14] Examples of linkages of these sorts appear in Thomas M. Stanbeck, Jr., "Short-Run Instability in the Cotton Broad Woven Goods Industry, 1946–1951," Unpublished Doctoral Dissertation, Duke University, 1954; and Ruth P. Mack, *Consumption and Business Fluctuations; A Case Study of the Shoe, Leather, Hide Sequence*, Princeton for NBER, 1956.

The Pieces of an Inventory Model

Fluctuation in ownership associated with changing market prospects, in which ecological interplay is of special importance, is of course only one part of the total process of fluctuation in stocks on hand and on order. Consequently the model of price-timed buying is only one piece of a complete model of fluctuation in materials inventories. Its particular function is to explain why even this most volatile set of influences does not imply a sawtooth pattern of fluctuation but instead tends to cause inventories to build up more slowly and necessarily to retard and reverse. Other aspects of an inventory model were discussed in Chapter 11, where differences were indicated in the picture appropriate to department stores and to durable goods manufacturers. The multiplier aspects associated with income and with expectations and their interrelationship were mentioned in Chapter 12. By way of summary I shall put the pieces

together largely as a sequence of empty boxes for which the previous discussions, especially the models of Chapter 11, serve to illustrate how they may be filled for various industries or other sufficiently homogeneous segments of the economy. A model for aggregate fluctuation in materials inventories would probably have to be built up by appropriate weighting of the segments.

The major pieces that need to be described and articulated are:

1. A forecasting procedure forming the basis of initial buying, which recognizes the information typically available to management and the time periods for which forecasts are actually required. This implies a basic distinction between firms having little advance knowledge of short-term changes in sales other than of a seasonal sort, such as retail stores, and firms for which sales orders or other trustworthy barometers provide a basis for reasonably good forecasts, such as many durable goods manufacturers. It also implies recognizing patterns of buying in terms of the overlapping time periods that the shingled structure of procurement frequently implies.[15]

2. A link of desired stocks to expected sales which for cyclical analysis is best formulated in incremental rather than average terms. My emphasis is negative—a constant average relationship ought not to be assumed. Even a constant incremental relation is of course a rough approximation, but perhaps close enough to realistic requirements to serve; presumably coefficients for increments would typically be smaller than the average ratio.

3. Changing opportunity costs of inventories which recognize changes in costs of carrying stocks, on the one hand (e.g., those associated with the presence of back orders or changes in the availability or cost of funds), and, on the other hand, of alternative ways of performing the functions that stocks serve (e.g., flexible employment or selling policies).

4. The influence of changes in market prospects and expectations concerning them on the timing of buying. This covers influences originating primarily from the supply as well as the demand side and their ecological interplay.

5. Methods of defining, recognizing, and correcting error; this is a complex element. It involves in the first place the relative importance of inventory goals in the framework of all management problems—the opportunity costs of management attention to defining and enforcing precise inventory goals. It involves correction in the second instance for faulty initial guesses about future requirements; the shingled pattern of buying mentioned in paragraph 1 has relevance here. It involves correction of procurement based on expectations concerning market conditions or other matters which are found to have been in error or which no longer apply.

6. An income and expectation multiplier. At any particular time net capital investment in inventories is subject to some sort of income multiplier at an aggregate level. But its effect can be muted or amplified depending on the interpretation placed on the change in inventories on hand and on order and the expectations thereby aroused.[16]

If the model is constructed in terms of ownership, all of the prescriptions can be viewed as applying roughly to the present in the sense for which the objectives and realistic judgments call. This makes it possible to net out some of the anticipations-correction procedures, such as those implied in the shingled orders (paragraph 1) and corrections (paragraph 5). The income multiplier in paragraph 6 operates with the lag

[15] See the discussion of department store orders and manufacturers' orders and shipments in Chapter 11. Note in connection with the latter that orders can provide a forecasting instrument even when goods are not made to order.

[16] Multipliers are a central point in the analysis that closes Chapter 12. Other specifics on this point appear at many places in the book, but note particularly the discussion of Exhibit 2, Cases I and II in Chapter 3.

implied by successive income receipt and spending sequences. The expectation multiplier in paragraph 6 operates with such lags as the ecological process implies. The latter statement applies in some degree to the expectational elements in any of the paragraphs, but particularly to paragraph 4.

If the model is constructed in terms of materials stock on hand, it is necessary always to allow for the time required for orders to enter stock and the corrections that have been put into effect during that time. Even the allowance for deliveries is difficult to make in view of the long and changing leads of outstandings relative to stocks.[17] The implications seem to be that the model loses most of its potential *analytic* value if applied to stock on hand. But it would be useful in gauging the gross influences on stocks of previous levels of outstandings. For example, in 1961 and 1962, when these levels were low, stocks would presumably tend not to be as high relative to activity as at other comparable cyclical stages—1950, 1954–55, 1958–59.

The importance that I assign to expectations and to the information conveyed by orders rules out period analysis of the Lundberg-Metzler variety. Response in terms of ownership is visualized as potentially immediate, whereas the situation to which buying responds evolves over time periods inherent to each particular sort of situation or process.

DIRECTIONS FOR FURTHER STUDY

I mentioned at the close of Chapter 3 that the strategy of scientific advance often means that a good question answered badly may be a necessary prelude to a good answer some years later. The purpose of this book has been primarily to test the value of a question —How do flows of information, commands, expectations, contribute to the understanding of flows of goods and income? The broad question has sired a family of specific questions discussed at the close of Chapters 11 and 12. They are implicitly collected in a series of related boxes by the model that has just been outlined. Fill in the answers and the theory achieves a concrete form. At any rate, understanding grows. Work toward this end can, happily, utilize the great deal that has already been done. But it may be useful to discuss, without pretense of system, some of the work that needs doing.

Time Series. The most obvious need is for time series that reveal patterns of communication in the form of orders along with information about actions such as shipments or production. Required are data for the same firms on sales orders and purchase orders, shipments and receipts, and, if possible, flows at other critical points such as production starts or finished production. Information for the stock pools that these flows bound completes the statistical picture. By arranging the firms (or divisions of them) in vertically related sequences, it would be possible to trace the vertical transmission of demand through the economy. Such sequences could also be related to appropriate price information. Information for stages of an industry sequence would provide the wherewithal for examining how buying waves spread vertically. Information for groups of industries would provide insight concerning the lateral dissemination of fluctuation.

The report of the Consultant Committee on Inventory Statistics, made to the Subcommittee on Economic Statistics of the Joint Committee on the Economic Report in 1955, stressed the importance of information of this sort. It recommended improvement in the data for manufacturing stocks, shipments, and orders (Recommendation 10); it recom-

[17] See the discussion and illustrative example in Chapter 10.

mended that information on sales, new orders, stocks, and outstanding orders for major departments of department stores be collected (Recommendation 21). There has been a careful overhauling of the manufacturing data, but unfortunately the information is still less than what is needed to picture the flow of orders and output on a vertical or horizontal basis. For department stores the situation is sad indeed. Far from providing statistics on orders by departments, even the data for the total stores has been discontinued as of December 1963.

The capacity of time series to inform about vertical and horizontal communication of fluctuation would be greatly enhanced if data for individual firms were summarized in terms of distributions as well as in terms of the usual totals or averages. Certainly, for example, it would be useful to know something of the patterns of change in the distribution of firms in an industry with respect to the number of weeks' supply of materials held on hand and on order, and of rates of change in this supply.

Interviews. Statistical data of these sorts, data capable of indicating what is done with respect to purchasing and inventory problems, require the counterpoint of information bearing on why it is done. One way of acquiring this sort of insight is to ask the businessmen who make the decisions. I realize that the results of discussions are considered unscientific and subjective. Resorting to this method involves a trade-off: relevance is emphasized at the sacrifice of precision. But at the present state of the art, it seems clear that relevance is often a bargain purchase. In short, "It is better to be vaguely right than precisely wrong." [18] Specifically, systematic discussions with businessmen are required concerning the range of subjects covered in Chapter 2. We need to get richer and firmer knowledge about the structure of costs and opportunity costs bearing on stocks and purchasing. We need to understand the information systems that help to formulate and validate objectives. Questionnaires are, of course, entirely useless for this purpose, at least until far more is learned about what to ask and how to formulate questions. Indeed, even in an open-ended interview, specific questions about stocks are likely at best to be only a point of departure.

For example, if a department store executive is asked whether, when sales increase 5 per cent, stocks also need to increase in the same proportion, the answer may be something like this: When sales first increase 5 or even 10 per cent, stocks *need not* increase at all. But pretty soon, often in connection with the next periodic planning procedures, management will start to think that the high level is going to last. Then stocks will move up to their customary ratio to sales. But the question, "Why do stocks need to rise that much?" provokes answers which do not, to the businessman, seem to hold their ground when probed. The investigations that need to be made consist of the discussions that follow, in which the man of affairs who knows the stuff of which good decisions are made is provoked to explore the grammar of the prose he speaks so well.

Discussions are exceedingly flexible techniques of study and accordingly are sensitive to the preoccupations of the investigator. If interviews are to be fully useful, they must probe the subjective as well as objective factors that determine how information is selected, appreciated, and acted upon. Of special importance in the context of the ecological aspects is the role of learning and assurance. Is there evidence of the gradual buildup that the ecological model assumes? If so, what information is watched, how does action depend on the perception of what competitors, suppliers, or customers are doing or have done? How is such knowledge conveyed among competitors, suppliers, indus-

[18] The remark was attributed to Wildon Carr by G. S. Shove, in "The Place of Marshall's Principles in the Development of Economic Theory," *Economic Journal,* December 1942, p. 323.

tries? Also of particular importance to the model are insights that can provide a basis for estimating how proclivity distributions are shaped. Interviews and other sorts of information, then, can in effect help to redraw Figure 5 and to suggest how units move from one spot on the surface to another. The answers would doubtless be found to differ for various sorts of industries.

Econometrics. As indicated toward the beginning of Chapter 9, econometrics was tabled for the course of this investigation. One would hope that its talents could be enlisted to test some of the notions that have been put forward and to add quantitative dimensions. As mentioned earlier, both the investigations described in this book and further information of the sorts just mentioned are prerequisites. But even so, formidable difficulties persist in incorporating the insights of this study into equations.

The study has shown that an understanding of the behavior of aggregate stocks must be built up out of an understanding of a number of parts for which causality is reasonably homogeneous. The analysis throws some light on how the parts should be defined. But even so there are major hurdles to be leaped or circumvented.

A convincing statistical "explanation" of the behavior of stocks or ownership must reconcile the observed magnitude and timing of aggregate fluctuations with a realistic view of business operations. My findings have presented the hypothesis that efficient servicing of sales, other things the same, does not require fluctuations as large as those which the statistics show and consequently "other things" do in fact appear to change with business conditions. Econometric analysis is thus asked to identify these other things and measure their impact.[19]

At a statistical level, this underscores the usual difficulties of isolating factors which tend to parallel one another at least most of the time—factors such as shipments, sales orders, labor costs, capacity utilization, market stringency, opportunity costs of financing or expectations about each.

At an analytic level, the potentially immediate response of ownership implies that distributed lags are a receptacle for ignorance; even for stocks, lags must have a duration that makes sense in terms of specific management problems and procedures in the context of cyclical variation.[20] Finally, the interpretation of the meaning of coefficients is confused by the possibility of multidirectional causal relationships, including those of an ecological sort.[21]

With the help of information from interview studies, the ingenuity of econometric work may contrive to circumvent the worst of these difficulties. If so, it seems likely that

[19] Needless to say, the effort to identify influences on stocks other than that of sales is familiar to econometric analysis. But, as I pointed out in Chapter 1, the results seem to be less than satisfactory. A major difficulty is the too powerful influence of orders. If ownership rather than stock is to be explained, the difficulty can be described by saying that new sales orders (or backlogs) may be viewed as a cause and new purchase orders (or outstandings) are a result. The format of the analysis must somehow accommodate this distinction.

[20] In the context of seasonal variation, the lags would often be different, and this raises questions concerning the usefulness of analyses based on data that are not deseasonalized when seasonal patterns are strong. For example, unlike cyclical variations, seasonals in sales can often be quite reliably forecast; the relative importance of the several explanatory variables usually differs for cyclical and seasonal changes in stocks and ownership; the timing of the relations among the variables will differ. If seasonals are strong, the parameters of the equation system may tend to recite the seasonal rather than cyclical version of the story.

[21] These qualifications of the meaningfulness of gross correlation measures are superimposed on the worries expressed in Chapter 9, note 2, above. Indeed, perhaps the only honest test for association of these sorts abjures the comfort of the "one period change model" and endeavors to reproduce history by means of an equation system for a "process model"—one in which the influences presumed to be at work are fully specified and asked to churn out the resultant course of the dependent variable. (For an instructive comparison of the results of the two sorts of models, see Kalman J. Cohen, *Computer Models of the Shoe, Leather, Hide Sequence,* Englewood Cliffs, N.J., 1960.) Simulation may be a simpler and more flexible way to achieve a similar result.

individually fragile findings may gain collective strength by a comparison of the findings for a number of individual industries or departments of department stores. The coefficients developed for the several business situations ought to differ in fashions that seem sensible in the light of other knowledge about each situation.

Simulation. Finally, there are serious gaps of knowledge concerning how the individual's view of the problem, the information that he uses, the responses that he makes, are influenced by the market and how it responds to and generates new information. Processes involving information have been studied under the titles of cybernetics and information theory. The particular sorts of processes involved in the model of price-timed buying could be explored with the aid of the massive capacity of the computer to manipulate and memorize numbers. The technique of simulation is suitable and flexible. It has been repeatedly put to work on the problem of tracing, in accordance with stochastic principle, how individual behavior builds into a time course of aggregate behavior.[22]

But my study seems to call for something more than the now familiar notion of analysis with a "feedback" from the environment. The character of the feedback is critical: it is one for which the coefficients of reaction (at the individual as well as at the aggregate level) themselves change. As far as I know, the aggregate implications of this sort of process have not been explored. Interestingly enough, the closest thing to it that has come to my attention is in the field of epidemiology—the Reed-Frost model.[23]

One of the most attractive aspects of the technique of simulation is its capacity to test a theory constructed in terms of selected characteristics and behavior of individuals. The assumptions that are made must result in a spaced and self-reversing wave; of critical interest is the ten- to fifteen-month thrust. Simulation itself can indicate what values for chief components of the model will, and what will not, produce movements of the sort posited. It can indicate the support that is required from exogenous influences. It can indicate how sensitive the picture is to reasonable ranges of variation in critical pieces of the explanation.[24]

I have suggested a number of directions in which the effort to deepen understanding of the vertical diffusion of fluctuation associated with inventory waves may be pursued. They feature the effort to understand the behavior of individuals and how it generates

[22] See especially Guy Orcutt, "A New Type of Socioeconomic System," *Review of Economics and Statistics,* May 1957, pp. 116–123, and subsequent work of Orcutt and other contributors to the work of the Social Systems Research Institute, University of Wisconsin.

Needless to say, feedbacks can be represented in mathematical models also. James Duesenberry and Franco Modigliani took this approach in their models of consumer buying which introduced maximum past levels of income as an indication of changing standards of living. The advantage of simulation, as I see it, is simply, first, that a theory that proposes reactions of people to one another is put to a sharper test if the process is specified at the individual level. Second, the process is likely to imply response at an aggregate level which is nonlinear, and therefore likely to be lost if functional forms must be predetermined.

[23] Work in the field of mathematical analysis of epidemics started in the first decade of the century, when it was found that periodic recurrences of epidemics could be deduced from and described by information on the number of susceptibles, contact-rates, attack-rates, and recovery ratios. Theory developed over many years. However, deterministic models did not seem to square with the facts, and a stochastic model was introduced in the middle of the 1920's. Somewhat later, the notion of a threshold was introduced; the proportion of susceptibles in a community must be above some critical value.

The approach seems to be associated with the name of Lowell J. Reed and Wade Hampton Frost, who taught at Johns Hopkins University. But most of the written expositions and much if not most of the theoretical and empirical work appears to have been done by others. See Norman T. Bailey, *Mathematical Epidemiology,* London, 1957. There are also numerous articles in the journal, *Human Biology, A Record of Research,* September 1952, and in Jerzy Neyman, ed., *The Third Berkeley Symposium on Mathematical Statistics and Probability.*

[24] James Bettman intends to explore some of these questions through interviews and perhaps simulation in his doctoral dissertation at Yale University, Graduate School of Business Administration.

and feeds upon relevant information and changing objective situations. Knowledge of this sort seems to me to be necessary to scientific exploration of the process of economic change.

But it is perhaps not too visionary to hope that it may have some value in modifying the process. Most businessmen probably prefer to buy and sell in a relatively stable and predictable market. If so, fluctuations of the sort that have been discussed are undesirable. Understanding of how fluctuation is built up by the system whereby problems are perceived and solved by businessmen could be a first step in designing better ways of solving them—ways that subdue their innate tendency to generate and amplify fluctuation. Insights would bear particularly, I suspect, on the problem of sustaining business expansion.

If it is useful to trace the move-by-move pattern whereby expectations, actions, information, and situations feed upon one another in connection with the buying of materials by business enterprises, it should be useful also to trace analogous processes in other fields. Certainly, for example, the "fickleness" of consumers, or the lumped equipment purchasing of producers, or local "construction cycles" are not without strong elements of interplay among the actions of many individuals as well as between individuals and the business environment. Some elements of the price-timed buying model might be expected to apply—the hill-shaped frequency distributions of proclivities, the ceilings, the importance of assurance and learning, the time-consuming buildup of evidence, the changing patterns of market response. But many other elements would differ, particularly the length of most of the lags. Even trend growth, especially in developing countries, shares most of these elements.

Questions of these sorts, once raised, are hard to forget. Their hold is strengthened by the importance that we are learning to accord to rates of change in the economy—rates of rise during prosperity fast enough to maintain expansion but not too fast to be themselves maintained. Rates of change in ecological processes tend to be willful at the aggregate level. Hope of adjusting them to the requirements of stable growth seems to lie in understanding the underlying microprocess and how it cumulates. For this purpose the august tools of equilibrium analysis may be of limited use.