Volume Title: The Economics of Information and Uncertainty

Volume Author/Editor: John J. McCall, ed.

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-55559-3

Volume URL: http://www.nber.org/books/mcca82-1

Publication Date: 1982

Chapter Title: The Capacity Expansion Process in a Growing Oligopoly: The Case of Corn Wet Milling

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Chapter URL: http://www.nber.org/chapters/c4438

Chapter pages in book: (p. 259 - 316)

8 The Capacity Expansion Process in a Growing Oligopoly: The Case of Corn Wet Milling

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A central aspect of the dynamic problem facing the firm in an evolving industry is the decision about additions to productive capacity. Particularly in capital intensive industries, capacity decisions have long lead times and involve commitments of resources which may be large in relation to firms' total capitalization. If the firm fails to add capacity at the appropriate time, it not only loses immediate sales and market shares but also may diminish its long-run competitive position—if the firm adds too much capacity, it can be burdened with unmet fixed charges for long periods of time. From a competitive standpoint, additions to capacity can pose major problems since the matching of capacity to demand is often a major determinant of industry rivalry and profits. The problem is most acute in industries producing standardized products, where product differentiation does not protect firms against mistaken capacity decisions of others.

The capacity decision not only involves high stakes, but also is fraught with subleties. In the presence of lead times and lumpiness, it requires expectations about future demand. It also involves the oligopolistic interdependence problem, since the capacity decisions of competitors over the

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The authors would like to thank George Rozanski for his invaluable help with the computing of the model. His skill, speed, and patience contributed greatly to this effort. We have benefited also from comments at seminars at MIT, the Antitrust Division, the Harvard Business School, the University of Montreal, the UCLA Business School, the Harvard Economics Department, and the Yale School of Management. We thank participants in these seminars for their patience and constructive input. The members of the NBER seminar (whose papers appear in this volume) and especially Professor Sidney Winter provided extremely useful insights into the relationship between this type of model and the models of general equilibrium theory.

planning horizon will determine the profitability of decisions by a single firm. These complexities suggest that modeling the capacity expansion process in an industry may have a high payout in understanding the structural conditions which drive it, the nature of equilibria, and the implications for the optimal capacity decisions of individual firms.

This paper attempts to model the capacity expansion process through the analysis of a specific recent case: the corn wet milling industry. The corn wet milling industry is typical of many large, undifferentiated product industries in the economy and provides a useful setting for such a study. While the model developed here uses data from corn wet milling, its structure and the principles that emerge are applicable to the capacity expansion process generally. Part of our purpose, however, has been to show how economic analysis can play a role in setting corporate investment decisions. For this purpose, the case study seemed well suited.

In carrying out this case study, we had several objectives. The analysis done here is similar to the analysis that would be carried out by a firm doing a careful job of corporate planning leading up to a major investment decision. We wanted to understand what the ingredients in such a problem looked like from the decision maker's standpoint. Of central concern was the predictability of the behavior of rivals and the analysis that would go into such predictions. It is our tentative conclusion that starting from common views about the nature of the market opportunity, firms can develop consistent views about their rivals' behavior and the returns to their own investment. Part of our purpose is to set out one version of the analytical model that would give rise to these shared and consistent predictions. This aspect of the study could be titled "The Structure of the Dynamic Equilibrium."

In addition to the model itself, we have been interested in the way in which the dynamic equilibrium varies with the underlying structural attributes, particularly the amount of uncertainty about demand for the product. The paper contains several observations about the impact of uncertainty on investment decisions and industry evolution. These are thoughts that could be developed further, using a theoretical model.

There are interesting differences in the ways in which firms respond to risks that emerge in the case study and that influence their investment decisions.

These and related issues need not be studied exclusively in the context of a case study. Indeed, they would not, but we found that the case study which forces one to attend to what the decision maker would find important and does not allow one to ignore relevant features of the problem is a useful way of locating the central conceptual issues and of shedding some light on the determinants of the evolution of industries in what (from a static point of view) is a disequilibrium situation. It is our hope that researchers in economics and business administration will find the approach useful and provocative.

The paper can be read in a number of ways, depending upon the reader's interest in the details of the analysis of the corn wet milling case. Section 8.1 describes the corn wet milling industry and a major investment opportunity presented by high fructose corn syrup. Section 8.2 discusses the model used to analyze the capacity expansion process in the market. The next six sections (8.3 through 8.8) present the details of corn wet milling economics and the assumptions of the model. Section 8.9 describes the equilibrium in the market. Sections 8.10 and 8.11 discuss the effects of varying degrees of uncertainty on the capacity expansion process and the sources of the expectations of firms in the industry.

Some readers may be interested more in the approach and the model than in the corn wet milling industry. Our suggestion would be to read section 8.1 as an introduction, and then read section 8.2, 8.9, 8.10, and 8.11.

8.1 The Corn Wet Milling Industry

The corn wet milling industry[1] converts corn into two major end products: cornstarch and corn syrup.[2] Except for a small fraction of industry output, cornstarch and corn syrup are commodity products, sold primarily to the food, textile, paper, and adhesives industries. Starch is used primarily as a stiffening and texturizing agent, while corn syrup is used as a texturizer, thickener, and sweetener.

Corn is ground into starch slurry (this operation is termed "basic grind"), which can be either further processed into finished starch or converted into corn syrup through a chemical process. Industry production uses continuous process technology, and the size of efficient increments to capacity is large. The minimum efficient scale plant processes 30,000 bushels of corn per day and represents an investment cost in excess of $30 million. Efficient increments to capacity are equally large. To put this in perspective, the total grind capacity of the industry in 1972 was 108 million bushels per day, the equivalent of thirty-six minimum efficient scale plants.

The corn wet milling industry had been a stable industry for decades, dominated by Corn Products Company (now CPC International) and consisting of approximately a dozen firms. Competition in the industry historically could be described as "gentlemanly." Through the 1960s and early 1970s, however, the industry was rocked by the entry of three "outsiders," all large commodity processing and trading firms (Grain Processing, Cargill, and Archer-Daniels-Midland). A period of intense industrial warfare and severe price competition periodically characterized the industry from the late 1960s until 1972 as the new entrants were assimilated; a few firms left the industry in the process. By 1972 and into 1973, however, industry capacity utilization had risen back to high levels and the industry consisted of eleven firms.

In 1972, however, this old industry was confronted by a potentially revolutionary development—the commercialization of high fructose corn syrup (HFCS). HFCS, a commodity product, is a corn syrup very high in fructose, or sweetness. It is made by further conversion of conventional corn syrup to add to its sweetness content. HFCS is a substitute for sugar and is intrinsically somewhat cheaper to produce than sugar. If HFCS were to replace a significant proportion of sugar, this new product would approximately double the size of the corn wet milling industry. Thus, the exogenous shock of HFCS's commercialization in 1972, proved a reality by initial sales of the product to the food industry by corn wet millers Standard Brands, and Staley Manufacturing Company, confronted every firm in the industry with an important decision about adding capacity to produce the new product.

8.1.1 The HFCS Capacity Decision

The firms confronting the decision about HFCS faced a myriad of issues. The first was the expected level of demand and the rate at which users would convert from sugar to HFCS. The principal market for HFCS is the liquid sugar market of which soft drinks are the dominant end use. The growth of the HFCS market depended on the rate at which users reformulated their products to allow the use of HFCS, and hence on the level of sugar prices and the consequent inducement to reformulate. Although HFCS was believed to be almost completely substitutable for sugar, small and subjective changes in the taste of some products occurred. This required additional care in product reformulation, and though this was not costly, fears about not duplicating the taste of products was a barrier to changeover. Also, the somewhat different physical properties of HFCS required some product reformulation in some cases.

The incentive of the user to change over to HFCS depended on the spread between the cost of HFCS and the price of sugar. HFCS costs less to produce than sugar, but sugar prices were highly volatile. Sugar was traded in a very politicized world market, with less developed countries as major suppliers. Sugar prices were supported above world market prices by legislation in the United States. It was believed that the trend in sugar prices would be up reflecting increased costs of production, though predicting sugar prices over the long run was difficult.

HFCS demand also depended to some extent upon the HFCS capacity that was actually built. Large users of sugar were unlikely to convert to HFCS unless enough capacity was on-stream that they could be assured of gaining adequate supplies and would not be at the mercy of only one or two HFCS suppliers. Thus, demand and supply were interdependent; this guaranteed some temporary excess capacity if high demand for HFCS was to occur.

The second major issue facing a corn wet miller in deciding about HFCS capacity was what way to participate in HFCS. If a firm decided to begin HFCS production at all, it had a number of alternatives. Because high fructose production involved further conversion of corn syrup, a firm would enter the HFCS market by diverting capacity it had used for corn syrup production into HFCS. Alternatively, it could divert basic corn grinding capacity, but build additional facilities to produce corn syrup and convert it into HFCS. Finally, the firm could construct fully integrated HFCS capacity, consisting of corn grinding capacity, corn syrup refining capacity, and HFCS conversion capacity.

If a firm chose to divert either grind capacity or integrated corn syrup capacity into the production of HFCS, it was necessarily removing capacity from the corn syrup or starch markets. Thus, if enough corn wet millers diverted capacity, supply would be insufficient to meet demand in these other markets and prices in them would rise. As a result, the corn syrup and starch profits of each firm depended on the HFCS capacity decision of all the other firms.

Conversely, the fact that HFCS production was at the end of the continuous process technology with starch slurry and corn syrup as intermediate products meant that the construction of integrated HFCS capacity was not without risk for the starch and corn syrup markets. If the integrated capacity constructed by firms in the industry significantly exceeded demand for HFCS, then the output of the upstream stages of the HFCS production process could be diverted into the starch or corn syrup markets. What is more, grind and corn syrup capacity diverted for use in HFCS production could be put back into the starch and corn syrup markets. Thus, if the HFCS capacity exceeded demand, not only would HFCS prices be depressed, but the starch and/or corn syrup markets would deteriorate. Even if a firm chose not to enter into the production of HFCS, it could not escape the effects of HFCS if this scenario occurred, and its profits depended on the HFCS capacity decisions of its rivals.

The profitability of HFCS would depend on the spread between HFCS costs and prices. Prices would be a function of the capacity utilization in the industry and of the price of sugar. If the demand for HFCS were close to or exceeded the HFCS capacity put on-stream, then HFCS would be expected to be priced relative to sugar (at approximately a 15 percent discount). However, if there were substantial excess HFCS capacity, then HFCS would likely be priced relative to cost. A significant part of HFCS costs were variable, the major element being the cost of corn. However, there were fixed operating overhead and significant capital costs. Judging from experience in the starch and corn syrup markets, in periods of substantial overcapacity the price of HFCS was likely to be near variable costs.

Other issues were access to HFCS production technology and the likely future changes in that technology. HFCS production technology was being licensed in 1972 by Standard Brands, the pioneer producer. However, other firms were also offering technology, and it was believed to be within reach of all the participants in the corn wet milling industry in 1972, though they might face a modest delay if they chose not to license from Standard Brands. HFCS technology was sure to improve, but there were no predictions that the basic process would change so that firms could gain significantly by waiting to invest.

Finally, a firm choosing not to enter into HFCS production faced a number of risks besides those described above. It would forego having a full line of corn sweeteners, all of which were sold to basically the same group of customers who might value dealing with a full-line firm. It would also give up the sales revenue and cash flow of participation in this potentially large market. This could increase vulnerability to price wars and might have a cost in terms of less capital to invest in the industry.

In 1972 there were eleven major firms in the corn wet milling industry. A list of the competitors and their capacities for producing HFCS and other products (starch and corn syrup) is given in table 8.1. The analysis that follows is conducted in terms of operating profits and margins. For the record, however, the costs of HFCS are roughly as in table 8.2.

8.2 The Approach to Assessing Competitor Behavior and the Evolution of the Market

In modeling the evolution of the corn wet milling industry, one is faced (as an analyst and as a competitor) with complexity created by the very

Table 8.1 **Firms and Capacities in 1972 (millions of pounds)**

Firm	Capacity in Starch and Corn Syrup	HFCS Capacity
American Maize	761	0
Anheuser-Busch	317	0
Archer-Daniels-Midland	951	0
Cargill	1,193	0
CPC International	3,439	0
Grain Processing	1,396	0
Hubinger	634	0
Pennick & Ford	825	0
National Starch	571	0
Staley	2,021	200
Standard Brands	1,196	200
Total	13,304	400

Table 8.2 **Costs of HFCS**

Cost Component	Cost per lb. (¢)
Raw materials (net of by-products)	2–4
Variable processing costs	2–4
Overhead	1–2
Capital cost at full capacity utilization	2.5–4

large number of possible outcomes. Such complexity is often dealt with by using scenarios, and we employ that procedure here. Scenarios simply aggregate continuously varying outcomes into a manageable number of interestingly different groupings. Thus, instead of describing demand by its level each year, for example, one can approximate the full range of outcomes with low, medium, and high demand scenarios. There is of course a risk in proceeding in this way. The scenarios, being approximations, can be incorrectly chosen so as to obscure important differences. The alternative, however, is an unmanageably large number of variables that make rigorous analysis impractical.

The second reason for employing scenarios relates to the sequential character of capacity decisions. Capacity decisions are not made on a once-for-all basis at a single point of time by every competitor. There is in fact a sequence of decisions through time, with information from the market about demand, prices, and competitors' behavior pouring in. As a practical matter, this must also be simplified. The approach taken here is to characterize the industry's evolution in terms of scenarios for purposes of predicting the "first round" decisions of competitors. The alternative is to try to deal with the full sequence of decisions, a procedure that also quickly becomes impractically complicated.

The modeling effort is guided by the following broad structure. For the individual firm, the profitability of its operations and its HFCS capacity decisions are determined by two sets of factors: (*a*) the evolution of demand and sugar prices, the latter being a predominant influence on HFCS prices, and (*b*) the capacity expansion decisions of its competitors. The demand-related factors are subject to uncertainty. And as noted earlier, they are not independent of capacity expansion. The decisions of competitors and the implications of those decisions for industry capacity are to be predicted.

Competitor analysis and the prediction of the pattern of industry capacity expansion are the central focus of our analysis. The fundamental principle we employ in searching for equilibrium is that the predicted industry capacity and the predicted behavior of rivals must be *consistent*. Consistency involves the following chain of reasoning.

The capacity decisions of individual competitors will depend in part upon the industry capacity expansion path that they anticipate. These decisions will also depend upon their preferences, their attitudes toward risk, their financial resources, and other factors. While firms' decisions depend upon anticipated capacity in the industry, actual industry capacity clearly depends upon firms' capacity decisions. Consistency requires that the anticipated pattern of industry capacity expansion is that which results from the predicted capacity decisions of the firms in the industry, whose decisions are in turn conditional on the anticipated industry capacity. This consistency requirement is an equilibrium in the sense that expectations converge on outcomes that are consistent with the behavior of rivals.

There is of course no *logical* reason why firms could not have expectations that were inconsistent with the likely behavior of rivals. But it does seem reasonable to assume that as part of the process of generating and refining their expectations, firms will *check* their projections for aggregate industry capacity against their analysis of competitors' decisions in the light of industry capacity. Anticipating that other firms are engaged in the same process, a single firm should expect industry capacity expansion to be the result of predicted choices about rivals behavior, and it should expect rivals to come to the same or similar conclusions. Consistency then simply summarizes the idea that intelligent rivals will converge in their expectations about each others' behavior.[3]

The ingredients in the model are illustrated in figure 8.1. The figure can be read as follows. We begin at (*A*) with an assumption about the expansion of industry capacity over time. That, combined with random

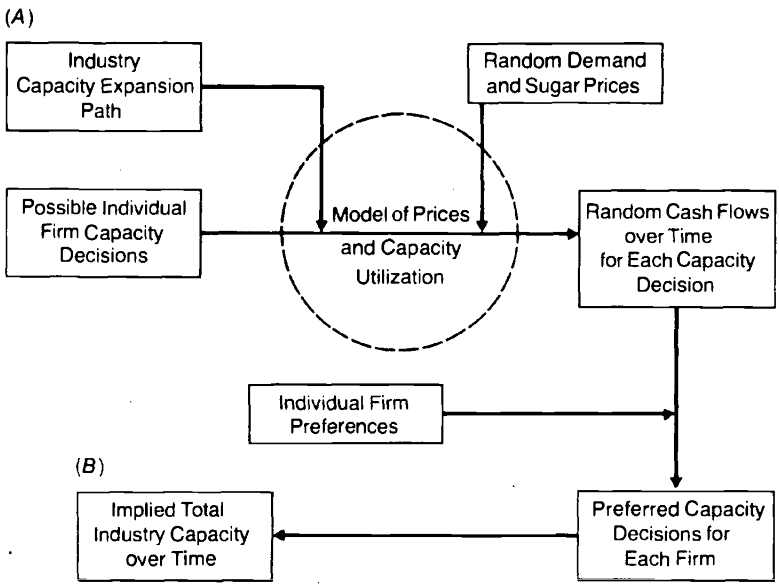

Fig. 8.1 Components of capacity expansion model.

demand, gives random net cash flows for each possible capacity expansion decision for each firm. The combining of demands, investment decisions by individual firms, and industry capacity expansion into cash flows over time involves an economic model of the industry. That model for corn wet milling is laid out in sections 8.3 to 8.8. The model takes capacity, demand, and sugar prices and generates prices, profit margins, and capacity utilization rates. The latter are then used to project cash flows for various possible investment decisions. The point is that there is a static industry model built in here.

In the language of microeconomics, the random cash flows that go with investment decisions can be thought of as the opportunity set, or, rather, the opportunity set, conditional on the industry capacity expansion scenario. In selecting a level of investment, the firm is selecting a random sequence of cash flows. Those random cash flows combined with firm preferences with respect to risk, return, and financial resources determine optimal capacity decisions for each firm. The individual firm investment decisions add up each year to give a time path for industry capacity (*B*). Note that the entire sequence is conditional on the starting assumption at (*A*). The consistency check is whether (*A*) and (*B*) are the same. A shared assumption about industry capacity which failed, via the process shown in figure 8.1, to generate the same industry capacity expansion path would not result from rational firm choices. It would therefore not be the assumption that careful firms would make. The expected evolution of industry capacity is that path that reproduces itself in figure 8.1. Then individual firm decisions and implied (uncertain) cash flows are the ones associated with that capacity expansion path.

From this description, it is easy to see that competitor analysis is the central feature of this model. The equilibrium is really the industry path that will withstand careful competitor analysis. Of course, if firms fail to check their assumptions in this way, then other paths could result. The hypothesis here is that they do.

This equilibrium assumption can be modified in a variety of ways to take into account the fact that firms' perceptions of uncertain events may differ and that their perceptions may be erroneous. The model allows firms' preferences, capabilities, and financial resources to influence their decisions. But the central organizing principle remains that anticipated growth must be consistent with rival firms' decisions, conditional on anticipated capacity growth.

It is worth noting that part of the economic structure of the model includes the assumption that there are no futures markets for high fructose corn syrup. Thus, firms cannot (and as far as we could tell did not) engage in futures contracts that assured both the quantity and price of future output from the plants they built. It is an interesting question why these markets did not exist. We will not try to give a complete answer here. We suspect that informational asymmetrics between the producers and buyers of HFCS concerning the completeness of the substitutability of HFCS for sugar made it difficult to structure contracts that would shift part of the risk to buyers or to third parties. Given that futures contracts did not exist, the planning process outlined in figure 8.1 can be thought of as a partial substitute for the price mechanism that would arbitrate these investment decisions in a general equilibrium world with a complete set of markets.

As Professor Winter points out in his insightful remarks in the comment to this paper, our hypothesis is that the evolving oligopoly, deprived of the full complement of markets required to guide investment decisions, *calculates* the equilibrium in the market and then makes the associated investment decisions. This calculated equilibrium is not the same one that would result with the full set of futures markets, because of the increased uncertainty that is created by the absence of those markets.

The detailed development of the model for the HFCS problem includes the following steps. First, a range of possible scenarios for demand and sugar prices is set out, with some assessment of their likelihoods. Next, a range of possible capacity expansion paths for the industry is constructed. Third, we assess the implications for profitability of a variety of capacity addition strategies for individual firms, conditional on demand and industry capacity expansion. Fourth, taking into account uncertainty about demand and individual firm characteristics, we determine the decisions the firms are likely to take, conditional on each of the industry capacity expansion scenarios. Finally, we ask which of the capacity expansion scenarios is most consistent with the sum of the capacity decisions of the firms. That becomes the predicted evolution of the industry and a prediction of the associated decisions for each firm. This sequence is carried out for the decisions taken in 1972 and checked against the historical record.

8.3 Demand and Sugar Price Scenarios

The potential demand for HFCS over the planning horizon depended on the proportion of sugar users who could be converted to HFCS. The 1972 demand for sugar was 14.3 billion pounds, of which 5.3 billion pounds was liquid sugar.[4] HFCS substituted for sugar on approximately a pound for pound basis. On the basis of the range of expert opinion in 1972, we can construct three scenarios for HFCS demand by 1980, as shown in table 8.3.

Demand is uncertain in two respects. The long-run size of the market and the rates at which actual demand would approach the long-run levels were matters of opinion. In constructing the scenarios depicted in table 8.3, we averaged over subgroups of a richer menu of scenarios consisting

Table 8.3 HFCS Demand in 1980 (pounds)

Sugar Prices	Low Demand (2.5 billion)	Medium Demand (5.0 billion)	High Demand (10.0 billion)
Low (8¢)	Scenario A	Scenario B	X
Medium (18¢)	X	Scenario C	Scenario E
High (28¢)	X	Scenario D	Scenario F

of various long-run demands and rates of adoption of HFCS by the major potential users.

Demand over the 1973–80 time period was assumed to be an S-shaped function of time, and the time paths for demand in each of the low, medium and high scenarios are shown in table 8.4. The S-shaped function was chosen to reflect the path of adoption usually followed by new products such as HFCS. Given uncertainties and the costs of changeover, users convert slowly in the early years, with changeovers occurring at an accelerated rate once large-scale changeover begins to occur. Actual HFCS demand in 1972 was approximately 400 million pounds.

Sugar prices over the planning horizon could also vary. We simplify by abstracting from the short-run variation in sugar prices and creating three scenarios for average sugar prices between 1972 and 1980, also shown in table 8.3. Sugar prices were widely expected to be in the eighteen cent range, and this is taken as the medium sugar price scenario. The low sugar price scenario represents the floor of industry estimates and past history, with the high scenario an arbitrary figure selected on the basis of past sugar price movements and expectations in 1972. It was assumed that although sugar prices would fluctuate in the short run, these fluctuations could be ignored, and the average figures were used in calculations over the planning horizon.[5]

Demand for HFCS and sugar prices are not independent, however, as discussed above. Therefore, all the possible combinations of demand and sugar prices portrayed in table 8.3 are not in the feasible set. Demand for HFCS is very unlikely to be high unless sugar prices are high, and vice versa. Using this principle, three of the nine combinations in table 8.3 were eliminated, leaving six demand/sugar price scenarios. These six scenarios became the exogenous environment or states of nature in the

Table 8.4 HFCS Demand Scenarios (billions of pounds)

	1973	1974	1975	1976	1977	1978	1979	1980
High demand	1.1	2.0	3.0	4.4	7.2	8.8	9.5	10.0
Medium demand	.7	1.0	1.4	1.8	3.0	4.0	4.5	5.0
Low demand	.66	.92	1.18	1.44	1.7	1.96	2.22	2.5

model. Firms' expectations over these scenarios were an important part of their decision making problem.

One might suspect that if the demand for HFCS were high and began to cut into the liquid sugar market, then the price of sugar would be cut as a response. Our view is that the HFCS market was not big enough to affect worldwide sugar prices significantly. Moreover, sugar prices appear to be set as a first approximation by raw sugar prices and a relatively stable refining cost and profit margin. Hence, the model takes sugar prices as random, but exogenous with respect to the development of the HFCS market. This is an approximation, one we felt did not do excessive violence to the facts.

One additional aspect of HFCS demand is built into the model, reflecting buyer behavior for this important input to their products. As described above, major buyers are unlikely to change over to HFCS unless sufficient capacity is on-stream to serve their needs without making them vulnerable to interruptions and bargaining power by a few suppliers. As a result, it is assumed that the high demand scenario cannot occur unless substantial capacity is added. This interdependence of supply and demand will be further reflected in the capacity/conversion scenarios described below.

Demand for products in the traditional corn milling markets—cornstarch and corn syrup—is assumed to be constant at 1972 levels. This corresponds to our use of 1972 figures for sugar demand. While both sugar demand and corn syrup/cornstarch demand were expected to grow, their expected rates of growth were similar and introducing growth into the analysis would needlessly complicate the model. The growth rates in the conventional markets were expected to be in the range of 3 percent per year.

8.4 Capacity Decisions of Competitors

To rationally make its own capacity decision, each firm had to predict the HFCS capacity that other corn wet millers would put on-stream and the degree to which they would convert capacity presently used in the other markets to HFCS. To do this, the firm had to assess each competitor's situation and predict the decision that the competitor would make. For purposes of the model, we simplify by assuming that the firm makes *aggregate* predictions about the behavior of its rivals. It predicts (*a*) the total HFCS capacity its competitors will add over the planning horizon and (*b*) the degree to which that capacity will be converted from uses in the corn syrup and cornstarch markets. The latter is critical because it will influence the supply/demand balance and hence prices in the markets for cornstarch and corn syrup.

We further simplify by abstracting the firm's predictions about the total capacity additions of its competitors into three capacity scenarios and into two scenarios about the extent of conversion. The scenarios for total capacity added are chosen to correspond to the demand scenarios described above. High total capacity additions by competitors will meet the total 1980 demand for HFCS in the high demand scenario, while medium and low total capacity additions by competitors will meet the medium and low 1980 HFCS demands, respectively. For the conversion scenarios, it is assumed either that competitors will convert no capacity—add all HFCS capacity on a fully integrated basis—or that 25 percent of the total HFCS capacity added by competitors will be converted from other markets. Moreover, since capacity equaled demand in 1972 for cornstarch and corn syrup, 25 percent conversion appeared to be the upper limit of the amount of capacity that would be converted in view of the profit potential in the other markets and the need to maintain customer relationships by serving their needs in the other markets. Heavy conversion of capacity increased the risk of alienation of customers in the other markets, many of whom would also be HFCS purchasers, and this could be especially serious if HFCS demand did not materialize.

The three scenarios for total competitor capacity additions are shown in table 8.5. The time path of competitor capacity additions was chosen to reflect lead times in capacity addition and the interdependence of demand and supply. Given the two-year lead time in adding integrated HFCS capacity and the one year needed to convert capacity, very little capacity could come on-stream in 1973 and 1974, which is reflected in all three scenarios. To achieve medium and especially high demand, much capacity would have to be put on-stream early in the planning period. Thus, we assume that capacity is put on-stream on an accelerated basis in 1975 and 1976, ahead of demand.

Where the capacity scenario did not match the actual HFCS demand scenario, excess or deficient capacity would become apparent in the

Table 8.5 **Capacity Expansion Scenarios (billions of pounds)**

	1973	1974	1975	1976	1977	1978	1979	1980	Demand
				7.25	8.1	9.25	10	10	High
High capacity	.6	2.0	6.0	6.0	6.0	6.0	6.0	6.0	Medium
				6.0	6.0	6.0	6.0	6.0	Low
				5.75	7.75	9.25	10	10	High
Medium capacity	.6	1.5	3.5	4.25	4.75	4.85	5.0	5.0	Medium
				3.5	3.5	3.5	3.5	3.5	Low
				NA	NA	NA	NA	NA	High
Low capacity	.5	1.0	2.0	3.0	4.25	4.85	5.0	5.0	Medium
				2.1	2.2	2.3	2.4	2.5	Low

industry by 1975 or 1976. Therefore, from 1976 onward, the assumed capacity expansion is chosen to reflect and is conditional on the level of demand in the HFCS markets. In table 8.5 each capacity expansion path branches into three subpaths in 1976, depending upon the observed level of demand. Thus, the pattern of capacity expansion from 1976 onward depends upon the demand-growth scenario that actually occurred.[6] Further, as argued earlier, high demand growth was very unlikely when capacity was low because the major buyers of HFCS were reluctant to switch over from sugar until there was sufficient capacity in the HFCS market to meet their needs. Later, in assigning probabilities to demand scenarios, we make the probability of high demand zero when capacity expansion is low.

8.5 Alternative Strategies

Each firm has a number of strategies available to it in HFCS. In the model, we allowed six possible strategies as shown in table 8.6. If the firm chose to do nothing, it simply continued to operate in the cornstarch and corn syrup markets. It could benefit if capacity was diverted into HFCS through conversion that removed capacity from those other markets, and it was vulnerable if excess capacity in HFCS caused the dumping of HFCS capacity into the traditional markets.

The most conservative strategy for entering HFCS production was to convert capacity from the other markets to HFCS by appending HFCS refining facilities to an existing plant. While a firm could theoretically choose to convert less, we assumed that the conversion option involved one minimum efficient scale, or MES. An MES plant has the capacity to grind 30,000 bushels per day of corn. A 30,000 bushel per day plant was capable of producing 357 million pounds of HFCS per year. The investment cost of adding HFCS refining capacity to an existing plant was estimated through industry interviews at $9 million, and conversion could take place in one year.[7]

More aggressive strategies were to build fully integrated HFCS capacity by either constructing a separate "greenfield" plant or adding another production unit to an existing corn wet milling complex. All options of constructing integrated capacity had an assumed lead time of two years. Firms could actually speed up construction slightly at an added cost. Two years was the most likely construction time, and the possibility of accelerated construction was eliminated from the model for simplicity.

The strategy of adding another production unit to an existing complex enabled the firm to economize on investment costs, because certain investments in infrastructure such as railroad sidings, storage facilities, and maintenance facilities could be shared. We have assumed that only one MES production unit could be added to an existing facility before

Table 8.6 Capacity Decision Options in HFCS

Strategy	Total HFCS Capacity On-Stream (millions of pounds)				Required Capital Investment (millions)				Total Investment (millions)	Change in Cornstarch/Corn Syrup Capacity (millions of pounds)
	1973	1974	1975	1976	1973	1974	1975	1976		
1. Do nothing	0	0	0	0	0	0	0	0	0	0
2. Convert one MES plant	0	357	357	357	$ 9	0	0	0	$ 9	−357
3. Add on one MES plant	0	0	357	357	$18	$18	0	0	$ 36	0
4. Construct one greenfield MES plant	0	0	357	357	$25	$25	0	0	$ 50	0
5. Select one add-on + one greenfield plant	0	0	714	714	$43	$43	0	0	$ 86	0
6. Select one add-on + two greenfield plants	0	0	714	1,071	$43	$68	$25	0	$136	0

new investment in infrastructure would have to be made, and we have further assumed initially that each firm had at least one existing corn wet milling complex where one such plant could be added at low investment cost. The investment cost for one MES greenfield production unit was estimated at $50 million, while the investment for an add-on unit was $36 million. These investment outlays were spread over the two years of construction. While the add-on strategy clearly dominated adding a greenfield plant if each firm was assumed to have one production complex where an add-on could be made, this assumption was easily relaxed later in the analysis.

The fifth strategy involved adding two MES units of integrated production capacity for HFCS. As in the previous options, the firm was assumed to have the ability to add on one unit at lower investment cost. It added the other MES sized unit through a greenfield plant at correspondingly higher investment. The final strategic option was to add three MES units of capacity, of which two were greenfield and one was add-on. This final strategy spread investment costs over three years, and capacity came on-stream in 1975 and 1976. All the strategies are described in table 8.6.

It was assumed that three MES sized production units was the maximum capacity any one firm could add in the HFCS market. This was based on the massive investment cost of HFCS capacity, but the option of adding a fourth HFCS production unit could be easily added to the model. We further assumed that mixed strategies involving conversion and construction of integrated HFCS capacity would not be adopted. This was because the conversion option was a low risk, low investment way to participate in HFCS which appeared to be inconsistent with making major investment outlays in constructing integrated HFCS capacity. While a firm might convert capacity in the short run to speed HFCS output onto the market, at the same time building capacity which would take a year longer to come on-stream, this tactical step was not allowed in the model for simplicity.

8.6 Expectations concerning Demand and Sugar Prices

How a particular investment appears to a firm will depend heavily upon the expectations with respect to demand and sugar prices described above in terms of scenarios. These expectations evolve over time as new information becomes available. It is possible for firms to have divergent expectations about these events, though there are forces that tend to produce convergent expectations (see section 8.11).

Initially, we have attributed to the firms the same views with respect to demand and sugar prices. We have also tested the sensitivity of the results to changes in these expectations. What actually occurred in the corn wet milling industry was a combination of unexpectedly high sugar prices in the 1973–75 period and an extraordinarily optimistic set of projections not only by firms, but also by securities analysts and other observers of the industry.

Table 8.7 gives the probabilities that were used for the purpose of calculating the expected present value and the standard deviations of returns to the various capacity expansion strategies. Note that when capacity is low, the probability of a high demand is zero. When capacity is low, the probabilities for the remaining demand and sugar price scenarios are the probabilities conditional on demand not being high.

Later, we report the effects of changing these probabilities. Those shown in table 8.7 reflect what appears to have been an optimistic view of the future, one that was widely held in the industry at the time. Little weight was given to low sugar prices, in part because the failure of Congress to extend the sugar price support legislation in 1974 was not anticipated. By 1974 sugar prices proved to be so high that the enactment of support legislation would have been politically infeasible. The long-run cost of refined sugar was believed to be in the neighborhood of eighteen cents per pound. The cost of HFCS, at 1972 prices of corn, was approximately ten cents per pound. Thus, while sugar prices could fluctuate significantly in the short run and while HFCS demand could develop slowly, the longer-term economics of HFCS success seemed reasonably assured.

8.7 Pricing, Capacity Utilization, and Supply/Demand in Starch and Corn Syrup

The next step in the model is to translate the demand and capacity scenarios into product prices and capacity utilization rates, in both high fructose corn syrup and the other markets for starch and corn syrup. We begin with HFCS. The capacity utilization rate in HFCS is the ratio of demand to capacity or the value one, whichever is smaller. HFCS is priced in relation to sugar unless there is considerable excess capacity in

Table 8.7 Demand and Sugar Price Risks

Demand/Sugar Price Scenario		Probability	
Demand	Sugar Price	Medium or High Capacity	Low Capacity
Low	Low	.05	.077
Low	Medium	.1	.154
Medium	Medium	.4	.615
Medium	High	.1	.154
High	Medium	.219	0
High	High	.131	0

HFCS. In the latter case, HFCS is priced close to operating cost.[8] With these principles in mind, we drew up the following pricing rules for the model: (*a*) If HFCS capacity utilization is less than 70 percent, then the HFCS operating margin is 2¢ per pound of output regardless of the level of sugar prices. This represents a loss, since capital costs are 2–2.5¢ per pound and overhead conservatively an additional 1¢ per pound. (*b*) If HFCS capacity utilization is greater than 70 percent, then the HFCS is priced in relation to sugar. Thus, if sugar prices are medium (18–20¢), the operating margin for HFCS is 10¢. If sugar prices are high, the operating margin for HFCS is 18¢ per pound. If sugar prices are low, the operating margin is 2¢ per pound of output.

With respect to the markets for starch and corn syrup, two possibilities arise. If capacity has been diverted to HFCS and is being used there, then there will be a capacity shortage in starch and corn syrup, putting upward pressure on prices. If on the other hand there is significant excess capacity in HFCS, that capacity can be diverted back into corn syrup, creating excess capacity and downward pressure on prices. With these principles, the specific assumptions are as follows.

Let H be HFCS capacity and c be HFCS capacity utilization. From the previous discussion let S be .25 if there was significant conversion (i.e., 25 percent) and zero otherwise. Excess capacity in starch and corn syrup is

$$E = H(1 - c - S).$$

The pricing rules are as follows: (i) if $E > 500$ million pounds, then operating margins on starch and corn syrup are one cent per pound, (ii) if $-500 < E < 500$, operating margins are three cents per pound, and (iii) if $E < -500$ million, there is a capacity shortage and operating margins are five cents per pound.

It remains to determine the operating profit for a typical firm in a given year. To do so, we need to specify how demand is allocated to capacity in each of the markets. In doing this, we have treated capacity in other products and excess HFCS capacity asymmetrically. The reasoning is that, provided prices are comparable, buyers of starch and corn syrup will stay with their regular suppliers rather than buy from an HFCS plant that has been opportunistically diverted back to starch and corn syrup because of excess capacity in HFCS. Thus, in starch and corn syrup, the old capacity, minus that which was converted, has first shot at the demand. Only if there remains some unsatisfied demand does the excess HFCS capacity get used to supply corn syrup and starch.

Suppose a firm has z units of HFCS capacity and t units of other capacity. Let c be the HFCS capacity utilization, m the HFCS operating margin, and q the starch operating margin. If there has been no conversion, there is no excess demand in starch and corn syrup. The profits of the firm are therefore $mzc + qt$. Here it is assumed that the firm's capacity utilization matches that of the industry. If there is substantial conversion (i.e., 25 percent of H), then there will be excess demand in starch relative to industry capacity. The excess demand is $.25H$. The capacity left over in HFCS is $H(1-c)$; thus, capacity utilization for the leftover capacity is

$$\min\left\{1,\left[\frac{.25H}{(1-c)H}\right]\right\}=\min\left\{1,\frac{.25}{1-c}\right\}.$$

The firm then gets additional profits of

$$qz(1-c)\min\left\{1,\left[\frac{.25}{(1-c)}\right]\right\}=qz\min[.25,1-c].$$

Therefore, for the high conversion scenarios the operating profits for the firm with z units of HFCS capacity and t units of other capacity are

$$mzc+q[t+z\min(.25,(1-c))].$$

This, in conjunction with the pricing rules and capacity-demand scenarios described earlier, permits one to calculate the operating profits and cash flows through time for each firm, for various combinations of industry capacity expansion, demand, and specific decisions by the firms.

8.8 The Calculation of Returns to Investment for Firms and Strategies

Using the probabilities described in the previous section, the assumptions about pricing and capacity utilization, and the firms' initial positions, we calculated for each firm the net cash flows of investment for each combination of capacity, demand, and strategy. Using a discount rate of 10 percent, the present values of the cash flows were calculated for each strategy-capacity-demand combination. Next, with the probabilities as in section 8.6, we calculated the expected present value of the net cash flows and standard deviation of the present value of the net cash flows for each strategy-capacity combination. Note that investment in starch and corn syrup capacity is taken as sunk; depreciation on this investment is not added back to cash flows, nor is depreciation subtracted from operating profit. Thus, we have a true measure of cash flows. These will be higher than reported profits because the latter have depreciation on old plant and equipment subtracted out.

The results are reported in appendix A, where there is one table per firm, each containing thirty-six boxes corresponding to strategy-capacity pairs. Thus, in table A-1 for American Maize, the upper left-hand box corresponds to the strategy of converting one minimum efficient scale facility and to the high capacity, high conversion scenario for the industry. Within each box in the tables there are five numbers. They are (a) the expected value of the present value of the net cash flows of investment (EPDV), (*b*) the standard deviation of the present value of the cash flows (SD), (*c*) the maximum present value across demand scenarios (PVMAX), (*d*) the minimum present value across demand scenarios (PVMIN), and (*e*) the smallest cumulative cash flow for any demand scenario for any year (CUMMIN). The fifth item requires brief comment. It is included as a measure of the financial resources the firm may have to mobilize in this market if demand is weak and things do not go well. As one would expect, these negative cash flows usually occur in the second or third year of the process when the major investments have been made, but before the majority of the returns are in. The figures differ from one company to the next because of initial differences in 1972 in overall grind capacity and in HFCS capacity. These initial capacities were reported in section 8.1.

The tables are to be thought of as summarizing the financial implications for each firm of combinations of their own strategy and the behavior in the aggregate of rivals. They do not tell us without further analysis what the behavior of rivals, individually or collectively, will be. Rather, they provide data on which to base judgments about competitor behavior and, hence, the most likely pattern of industry capacity expansion. We turn to that task next.

8.9 Analysis of Competitor Behavior, Expectations, and Market Equilibrium

In this section the principles described in section 8.2 are applied to the case at hand. We are looking for a hypothesis about industry capacity expansion which, when shared by the firms in the market, will lead to capacity expansion decisions that in the aggregate add up to that contained in the initial hypothesis.

The choices facing the firms are those described in the previous section and summarized in appendix A. The next step is to determine what choices the firms will make. This can be done in a variety of ways. One way is to apply decision criteria, such as mean-variance tradeoffs, relatively mechanically. We did not proceed in this way. Rather, we used the information that was available to us concerning each firm to make judgments about their strategic choices. The judgments about each firm's choice from its alternatives are based upon several kinds of information: (*a*) the financial consequences of alternative strategies, (*b*) the firm's size, financial resources, and strength, and (*c*) the historical behavior of the firm and the implications of that behavior for corporate goals, tolerance for risk, and aggressiveness.

In appendix B we have summarized the relevant characteristics of the firms with respect to deciding among risky investment alternatives. Using these facts and judgments, the "best" decisions for each firm conditional upon industry capacity expansion were assessed and are reported in table 8.8. At the foot of each column, the total HFCS capacity implied by the firms' collective decisions is reported, along with the fraction of that capacity generated by converting corn syrup and starch facilities.

Given our best estimate of the then-prevailing expectations about future demand, the equilibrium capacity expansion path in the industry is the medium capacity, high conversion scenario. If that outcome is anticipated, firms in the aggregate will choose to install fourteen MES HFCS plants, which would provide 4,998 million pounds per year of HFCS capacity over the first three to four years. Of that capacity, three to five MES plants will be converted so that conversion is in the range of 21 to 35 percent of HFCS capacity—with four conversions, the percentage is 28.

The medium capacity scenario has 3,800–4,250 million pounds per year of capacity by 1976, depending on actual demands. By 1977 that becomes 6,500 million pounds. Thus, the medium capacity, high conversion scenario had the required consistency property; the predicted behavior of firms is close enough to the initial hypothesis to be an equilibrium.

The other five capacity-conversion scenarios all generate behavior that is not consistent with the assumed scenario. The high capacity scenario leads to less than 3,000 million pounds of capacity, all of it converted. Neither the total nor the conversion rate matches the assumption of low capacity result. The medium capacity, low conversion scenario generates (through firms' decisions) 4,284 million pounds of capacity, which is consistent with the medium capacity hypothesis. However, the conversion rate is 66 percent, pointing back to the medium capacity, high conversion scenario as the most likely equilibrium.

In view of the expectations that were widely held in 1972 and that proved to be confirmed in the first two years thereafter, the equilibrium analysis suggests that fairly rapid expansion of capacity was predictable and consistent with informed strategic choices by rival firms in the industry. This is not to say that the choices that firms actually made (which proved to be close to those reported in table 8.8) were based upon precisely this kind of analysis. We do not know enough about the decision making process to be able to make that assertion.

However, we can examine the decisions firms actually took in the initial phases of the market's growth to the extent that we have data on them. Table 8.8*a* shows the capacity expansion in the industry through 1976.

The medium capacity scenario has higher capacity levels than those actually observed in 1973–76. However, this is partly a matter of timing. By 1976 the industry had under construction over 4 billion pounds of capacity, which came on-stream in the period following 1976. The medium capacity scenario is therefore reasonably accurate, though it

Table 8.8 Firm Strategies in HFCS, Conditional on Assumed Industry Capacity Expansion and Conversion Scenarios

	Assumed Capacity					
	High		Low		Medium	
	Low Conversion (25%)*	High Conversion (0%)*	High Conversion (25%)*	Low Conversion (0%)*	High Conversion (25%)*	Low Conversion (0%)*
Company:						
American Maize	Convert	Convert	1 add-on + 1 greenfield	Convert	1 add-on	Convert
Anheuser-Busch	Convert	Convert	1 add-on	Convert	Convert	Convert
Archer-Daniels-Midland	Convert	Convert	1 add-on + 2 greenfields	1 add-on + 1 greenfield	1 add-on + 2 greenfields	1 add-on + 1 greenfield
Cargill	Convert	Convert	1 add-on + 2 greenfields	1 add-on + 1 greenfield	1 add-on + 1 greenfield	Convert
CPC International	Convert	Nothing	1 add-on + 1 greenfield	1 add-on + 2 greenfields	Convert	Convert
Grain Processing	Nothing	Nothing	Convert	Convert	Convert	Convert
Hubinger	Nothing	Nothing	Convert	Convert	Convert	Convert
Pennick & Ford	Nothing	Nothing	Convert	Convert	Convert	Convert
Staley	Convert	Convert	1 add-on + 2 greenfields	1 add-on + 1 greenfield	1 add-on + 1 greenfield	Convert
Standard Brands	Convert	Convert	1 add-on + 2 greenfields	1 add-on + 1 greenfield	1 add-on + 1 greenfield	1 add-on + 1 greenfield
Implied outcome	7MES = 2,499M lbs. 100% conversion	6MES = 2,142M lbs. 100% conversion	20MES = 7,104M lbs. 15% conversion	16MES = 5,712M lbs. 31% conversion	14MES = 4,998M lbs. 28% conversion EQUILIBRIUM	12MES = 4,284M lbs. 66% conversion

*Amount *H* from conversion.

Table 8.8a **Industry Capacity Expansion (billions of pounds)**

	1973	1974	1975	1976
Actual industry capacity (estimated)*	0.6	1	1.4	2.2
Medium capacity scenario	.6	1.5	3.5	3.5

*Based on sales, assuming full capacity utilization during 1973–75.

predicts the building of capacity somewhat earlier than it actually occurred.

We cannot be sure of the individual company capacity decisions. Archer-Daniels-Midland had close to 1 billion pounds of capacity by 1976.[9] The other predictions in table 8.8 generally correspond to what we know about the behavior of other competitors.[10]

This history of the events in the market is interesting. In 1973 the industry capacity expansion began accelerating. There was great enthusiasm on the part of industry participants and analysts. Demand growth was aided by a tremendous surge in sugar prices in 1974. Amstar, a leading sugar producer, entered HFCS to protect itself in the sweetener market. However, at the end of 1974 the sugar price support legislation in the United States lapsed and was not renewed because of high sugar prices. The latter then tumbled to the eight cent per pound level. This adversely affected the HFCS market. By 1976 the capacity planned in 1973–74 was coming on-stream, while demand was falling off. By late 1976 industry capacity utilization was low (in the neighborhood of 60 percent) and the profits had been squeezed out of the margins in the industry. By 1977 analysts were predicting a return to full capacity only by the end of the decade.

8.10 The Effect of Expectations, Risk, and Uncertainty on the Evolution of the Market

The behavior of the firms, the nature of the equilibrium, and the character of the evolutionary process depend upon the underlying expectations about demand. This section is devoted to the relation between uncertainty and the equilibrium expansion path for the industry.

Uncertainty acts as a stabilizing and leveling force in the capacity expansion process. In the HFCS problem there was considerable uncertainty about demand. As a firm increased its level of investment in HFCS capacity, it increased its mean return, but it also increased its risk and exposure to very poor outcomes, as is readily apparent in the tables in appendix A. This exposure causes even the less risk-averse firms to choose to limit their investment, even when the expected return is high. Under different circumstances involving lower risk, a strategy of aggressively preempting more of the market might have been desirable. But with significant downside risks, taking a dominant market share was not a prudent strategy.

We can illustrate the role of uncertainty in firm behavior by examining the effects of changes in the expected probability distribution of demand on the risk-return trade-off of alternative strategies under various assumed capacity scenarios. Figures 8.2, 8.3, and 8.4 plot the undominated strategies in risk-return space for firm 1 (American Maize) for several probability distributions and the low, medium, and high capacity addition scenarios (all with high conversion). The horizontal axis is the expected present value, and the vertical axis is the standard deviation. The strategy option corresponding to each point on the graph is the circled number, and the bracketed numbers are the probabilities assumed.

In the low and medium capacity scenarios, more aggressive strategies generally increase return but always increase risk. In the high capacity scenario, more aggressive strategies often lead to lower expected returns and higher risk. Increasing uncertainty raises the risk for each strategic option and rotates the risk return frontier leftward. This makes more conservative strategies more likely, holding firms' risk-return trade-offs constant. Where firms have varying risk postures, uncertainty thus makes firms' optional choices increasingly dependent on their tolerance for risk.

In the analysis in table 8.8, where the equilibrium is portrayed, the largest projected share of capacity for a single firm is 21.4 percent. It belongs to Archer-Daniels-Midland. The original two firms that were participants in HFCS, Standard Brands and Staley, end up with 18.2 percent of capacity each, while the fourth largest firm is Cargill with 14 percent of the market. The resulting four-firm concentration ratio is 70 percent. This is high, but is not the industry dominance one would expect if one or two firms aggressively preempted the market. Uncertainty, then, represents a significant qualification to the strategy of preemptive capacity expansion and growth.

To see just how central the role of uncertainty is, it is useful to consider how the strategic opportunities would appear when risks are significantly lower. It is not difficult to see that with little or no exogenous risk, the ultimate size of the market is known almost with certainty. Under these circumstances, the strategies can be ordered unambiguously. Depending on the known demand, the firm will either do nothing or build to the limit. This can be readily seen in figures 8.2, 8.3, and 8.4, where removing uncertainty makes the risk-return lines horizontal.

With no uncertainty, preemptive investment, limited only by the financial resources available to the firm, becomes the appropriate strategy because it clearly maximizes discounted cash flow. The issue in the capacity expansion process becomes one of who can move first and fastest to occupy dominant positions in the industry, because there is only so

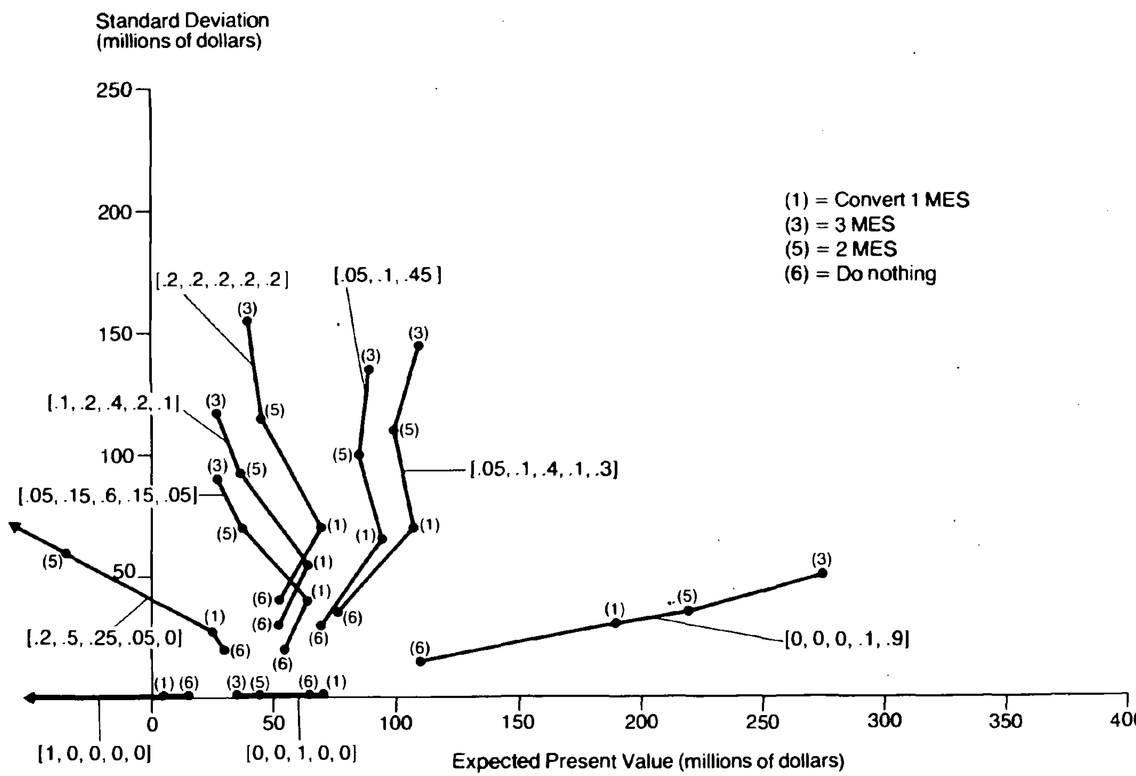

Fig. 8.2 Expected values and variances of strategic options with alternative expectations about future demand. Firm: American Maize. Capacity scenario: high capacity, high conversion.

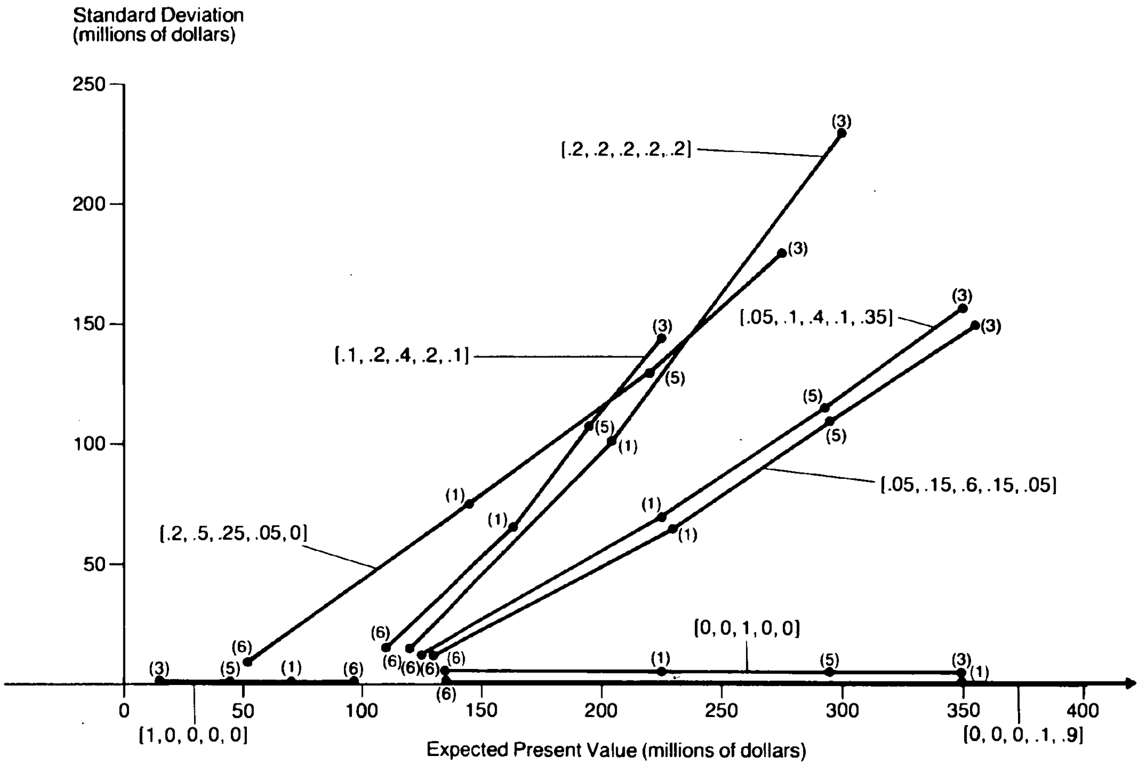

Fig. 8.3 Expected values and variances of strategic options with alternative expectations about future demand. Firm: American Maize. Capacity scenario: low capacity, high conversion.

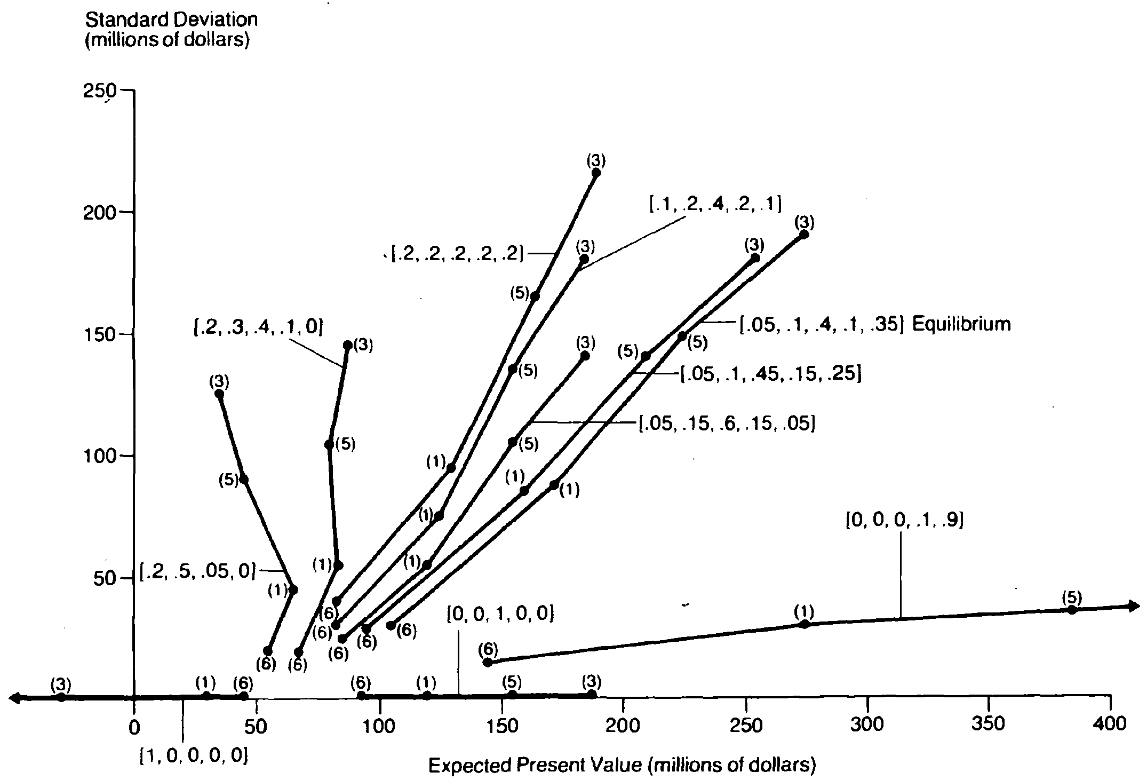

Fig. 8.4 Expected values and variances of strategic options with alternative expectations about future demand. Firm: American Maize. Capacity scenario: medium capacity, high conversion.

much known demand to serve. Under these circumstances, however, the firm faces the problem of other firms with the same idea.

In formal terms, the reduction of uncertainty transforms the game from one with a single equilibrium to one with many equilibria. Without uncertainty, the optimal strategy for each firm is to expand capacity so as to supply whatever demand is not covered by rivals' known capacity. Thus, there are multiple equilibria depending on whether one firm gets a jump and supplies the whole market or various combinations of firms do. The problem for the individual firm is to ensure that the equilibrium that is achieved is as favorable to it as possible. That entails expanding as fast as possible itself, but ensuring that others do not. This requires trying to preempt by means of public announcements of major capacity and contracting very early for the construction of facilities. If preemption is attempted by many firms and fails, then massive overcapacity will result. Thus, with no uncertainty about demand, a new form of risk may emerge to replace it. With significant uncertainty about demand, this form of risk is not important because preemption is not a rational strategy except under extreme risk-taking behavior. From inspection of figures 8.2, 8.3, and 8.4, it is clear that as uncertainty about demand is reduced, a firm's risk-return frontiers or options become flatter and flatter, and strategies of preemption (and therefore multiple equilibria) increasingly likely.

Unless firms lack an aversion to risk and can bear significant drains on cash, uncertainty will cause them to prefer and to choose lower levels of investment in the market.[11] At least over a range, increases in uncertainty are likely to reduce the range of equilibrium market shares because individual firms will not choose to attempt a preemptive investment strategy. One important implication of this line of reasoning is that an industry that evolves in an uncertain environment is likely to end up less concentrated than one whose evolutionary growth phase is characterized by greater certainty about future demand. Certainty in the evolutionary phase will lead to competitive warfare, the exit of firms, and the potential for high concentration.

These observations require some qualification. As a first approximation, an increase in uncertainty causes the desired levels of capacity to fall. That may or may not reduce concentration depending upon whether the less risk-averse firms contract relatively more than do the more risk-averse firms. There are two forces at work. As the uncertainty about demand increases, firms reduce planned investment. As a result, firms just on the margin of entering may find entry attractive where they did not before, because of the contraction of the larger firms. On the other hand, when investments of firms that were in the market are held constant, an increase in risk reduces the attractiveness of the market. It seems reasonable to hypothesize (and Spence 1979b has been able to show) that under certain conditions, concentration is a U-shaped function of risk. That is, as demand uncertainty increases, beginning at a low level, the number of firms that find it attractive to enter at some scale rises. But as the risk increases further, the market becomes unattractive to the more risk-averse firms in spite of the reduced levels of investment of the larger, less risk averse rivals.

In these terms, the HFCS case would be regarded as an intermediate one. The risks were high enough to prevent any firm from making a large enough investment to achieve a dominant share (40 percent or more of the market). But the risks and costs were not so large as to prevent smaller firms from entering the HFCS market at relatively small scales.

The model assumes constant returns to scale in HFCS production beyond a one-MES add-on strategy, and no reduction in costs owing to a learning curve, for early entrants. This is because most observers believed these assumptions were largely accurate in the corn wet milling industry. However, such cost behavior could be added to the model. The effect would be to flatten the risk-return trade-offs of alternative strategies and increase the attractiveness of larger investments by individual firms, particularly those that were more prepared to take risks.

The HFCS market was in some sense an intermediate case. Risk was high, but not so high as to force everyone into adópting the most conservative strategies. Also, in HFCS as in other markets firms differed in their attitudes toward, and tolerance for, risk. Thus, their choices ranged from no investment, to a small-scale conservative entry, to modest commitment to a leadership position. No one could justify a preemptive attempt to capture a dominant share.

8.10.1 Different Expectations and Equilibrium

Apart from uncertainty and risk, different expectations could have caused a dramatically different evolution in the HFCS market. For example, with less optimistic expectations, the low capacity scenario with a substantial amount of conversión would have been the outcome. With the probabilities shown in table 8.9, the model yields a low capacity expansion outcome with 50 percent conversion, as shown in table 8.10. As was the case earlier, the strategies adopted by firms are based upon the calculated present values and cash flows for each firm, and an assessment of their attitudes toward risk and their financial resources.

Similarly, with very optimistic probabilities, a high capacity equilibrium could have developed in the market. However, with probabilities attached to high demand sufficiently elevated to justify investing in the

Table 8.9 **Probabilities Yielding a Low Capacity Equilibrium**

Demand	Low	Low	Medium	Medium	High	High
Sugar price	Low	Medium	Medium	High	Medium	High
Probability	0.3	0.55	0.15	0.0	0.0	0.0

Table 8.10 **Low Capacity Equilibrium**

	High Capacity		Low Capacity		Medium Capacity	
	25% Conversion	0 Conversion	25% Conversion	0 Conversion	25% Conversion	0 Conversion
American Maize	Nothing	Nothing	Convert	Convert	Nothing	Nothing
Anheuser-Busch	Nothing	Nothing	Convert	Nothing	Nothing	Nothing
Archer-Daniels-Midland	Nothing	Nothing	1 add-on	1 add-on	1 Convert	1 Convert
Cargill	Nothing	Nothing	1 add-on	1 add-on	1 Convert	1 Convert
CPC International	Nothing	Nothing	Convert	Convert	Nothing	Nothing
Grain Processing	Nothing	Nothing	Nothing	Nothing	Nothing	Nothing
Hubinger	Nothing	Nothing	Convert	Nothing	Nothing	Convert
National Starch	Nothing	Nothing	Nothing	Nothing	Nothing	Nothing
Pennick & Ford	Nothing	Nothing	Convert	Convert	Nothing	Nothing
Staley	Nothing	Nothing	1 add-on	1 add-on	Nothing	Convert
Standard Brands	Nothing	Nothing	1 add-on	1 add-on	Nothing	Convert
Total	0 capacity	0 capacity	9 MES = 3,213M lbs. 55% conversion	7 MES = 2,499M lbs. 42% conversion EQUILIBRIUM	2 MES = 714M lbs. 100% conversion	5 MES = 1,785M lbs. 100% conversion

face of a large total industry capacity, the variance of returns tends to fall. As the earlier discussion of risk indicated, this will push firms toward preemption, and the market toward multiple equilibria. Applying the technique used in the previous section will not guarantee an equilibrium. There is too much "doing the same thing": either very large expansions or doing nothing. This, of course, is exactly what one would expect. With demand uncertainty hypothetically reduced, the principal differentiating feature of firms, their attitudes to and tolerance for risk, becomes less and less relevant.

8.11 Expectations and Risk Aversion in the Capacity Expansion Process

Our model has treated firms' expectations about future demand and competitor behavior as exogenous and independent. We have treated the risk aversion of firms as independently and exogenously determined as well, and our judgments about each firm's trade-off of risk and return were based on assessments of the backgrounds of each firm's management, the place of the corn wet milling operation in each firm's overall operations, and other factors described earlier. Yet neither firms' expectations about the future nor their risk aversion is necessarily independent and exogenous in the capacity expansion process. There are strong reasons to suspect that both are generated endogenously through a variety of processes that will be crucial to further understanding the capacity expansion decisions that actually take place.

8.11.1 Expectations about Future Demand

Firms form their expectations about future demand in part through independent analysis and discussions with customers. However, all firms in the industry obtain information about future prospects directly or indirectly from many common sources. There are mechanisms which cause expectations to converge and perhaps also to inflate.

One common information source used by firms is the limited number of prospective customers, most of whom firms already serve with other products. Through these common buyers all firms will have access to essentially similar views of customer needs.

A second common source of information comes from the interaction between firms and the capital markets, where the security analysts play a major role in information flow and expectations creation. Security analysts are in business to recommend purchases of stock based on company research. They develop predictions of future demand that are published and widely read by industry participants. Analysts rely heavily on interviews with industry participants in information gathering, and hence provide another mechanism for the circulation of predictions about the future among firms and thus for the convergence of expectations.

They also interview customers and other industry observers, from whom many of the firms also gather information.

Embedded in this argument is a view that capital markets are imperfect in an informational sense. Lacking full information about the future, the capital markets react to signals about future conditions of firms. These signals take the form of statements by management and historical firm results, filtered through security analysts. Major investment decisions are also signals, taken in the context of a general overview about the propriety of making them, as portrayed by analysts and the financial press. There is therefore a significant role for security analysts and the capital markets in the capacity expansion process.

Through analysts, firms can play a role in creating an optimistic bias in judgments about future demand. Firms seek to maximize the price of their shares. They do this by portraying the future as optimistically as they can to analysts. While overoptimistic predictions by firms about the future carry the risk of failure to deliver, it can be argued that investors have short memories and that rationalizations for results below forecast are usually available. Thus, the increase in stock prices generated by optimistic predictions about the future are greater than the negative movements in stock price caused by unrealized predictions. If firms attempt to portray themselves optimistically, then this information is circulated through the security analysts to other firms, tending to inflate other firms' predictions through a risk aversion process that will be described below.

Firms also communicate with one another through their public statements in the press, through their annual reports and other public documents, and through appearances by management before groups of security analysts. This communication provides a mechanism for expectations to converge.

Finally, firms communicate expectations to one another through actual decisions to commit resources. If one firm announces a capacity decision, this communicates that firm's implicit expectations about demand to the other firms in a particularly credible fashion. Thus, there is a wide variety of mechanisms to aid in convergence of expectations about future demand.

A firm might try to use these mechanisms to create mistaken expectations about the future. A firm would gain, for example, if every other firm thought future demand would be low when it really would be high. The bluffer could build capacity sooner, and reap the benefits while its rivals caught up. However, communicating such mistakenly negative expectations worsens the firm's position with the capital markets and thus carries a cost to the firm. Perhaps as a result, one rarely observes firms making bearish statements about future demand. At worst, demand is expected to be "temporarily" depressed or "temporarily" modest, while the future holds great promise.

In most markets, including the corn wet milling industry, it makes little sense for the firm to create mistakenly high expectations about demand in its rivals. This is because doing so will create excess capacity, hurting the firm as well as its rivals, though its rivals will be hurt more if they build mistakenly. Such an incentive not to overinflate rivals' expectations goes directly against the pressure to paint an optimistic picture of the future to the capital markets.

A final factor to be noted about future expectations is that many managers seem to prefer progress and making positive moves to pessimism and inaction. It is also human nature to be optimistic about the future if possible. This may create an additional optimistic bias in future expectations.

8.11.2 Risk Aversion

A firm's risk-return trade-off function is due in part to a wide range of factors specific to its particular situation. However, there is a sense in which the risk aversion of firms in a market is partially endogenous. Consider a situation where there are long lead times in building capacity. Suppose a manager has the choice of building capacity or not building it, with future demand being either high or low. As table 8.11 shows, if the manager chooses not to build, his best outcome is satisfactory profits in the event that demand proves to be low. But suppose he chooses not to build, demand proves to be high, and all of his competitors build capacity. Here the manager is in difficulty; his incorrect decision is hard to explain. On the other hand, if he builds capacity along with all his competitors, if demand proves to be low, then blame can be shared or attributed to industrywide factors out of his control. Thus, the risk averse manager may well build capacity even if doing so would not be justified by the firm's true expectations about the future and risk-return indifference curve, provided other firms in the industry are building capacity. If no other firm builds capacity, it will be a rare manager who builds unless his beliefs about the future are extremely strong (or he ignores uncertainty).

This analysis would suggest that once a few firms have announced capacity additions in a market, particularly if they have at the same time

Table 8.11 **Outcomes of Building Decisions**

	Future Demand	
	High	Low
Build	High profits	Low profits
Don't build	Lost profits	Medium profits

communicated optimistic expectations about future demand through the mechanisms described earlier, many firms will rapidly announce capacity additions. This bandwagon effect would tend to produce excess capacity in the industry and work against any but a high capacity equilibrium in our sense.

The bandwagon effect is reinforced by the capital markets if security analysts hold positive expectations about the future. Pressure from analysts and stockholders on management to build capacity will grow within firms which have not announced capacity additions. In fact, announcements of capacity additions may become key signals to the stock market which result in share price increases. Thus, in the face of generally optimistic expectations about future demand, even though there may be great uncertainty there will be a strong tendency toward overbuilding of capacity through shifts in the shape of firms' indifference curves.

If this bandwagon process is present, then a preemptive strategy by one or more firms can be disastrous. A preemptive strategy, accompanied by aggressive language about future expectations and planned behavior, can virtually guarantee upward-spiraling capacity additions.

8.12 Conclusions

It may be useful to conclude this analysis by underscoring the major points and by identifying areas in which further research would yield a high payoff.

The main point is that it is possible to calculate the most likely capacity decisions for firms in an expanding market. Those calculations are based upon the assumption that firms will come to a common view about each other's decisions. They will do this by analyzing their competitors' decisions, conditional upon hypotheses about the rate of capacity expansion in the industry, thereby finding the capacity expansion hypothesis that is consistent with the decisions that are expected, conditional on that hypothesis. Capacity expansion scenarios that are consistent with individual firm decisions are referred to as "equilibria."

As a prediction about what will happen in a market, such equilibria seem to us a natural focus of attention. Using the beliefs about the market potential that prevailed in the industry, the resulting medium capacity, high conversion equilibrium is a reasonable approximation to actual behavior in the corn wet milling industry. But several qualifications are in order. First, firms may make mistakes about their competitors' preferences, capabilities, and financial resources. This introduces some slippage, in the form of increased uncertainty, into the process. Second, firms may fail to analyze rivals carefully; they may make assumptions about industry capacity that would not be borne out by a careful analysis of competitor decisions based on a shared industry capacity assumption.

Third, firms may have different views about demand: its expected level and the uncertainty surrounding it. This may cause their behavior to diverge from that predicted by a rival which approaches the demand side of the capacity decision problem with different judgments about the future.

The second point that emerges is that the equilibrium outcome varies with expectations concerning demand and market potential. The entire equilibrium analysis rests upon assumptions about the likelihood of various rates of growth of the market. We have argued in section 8.11 that there are factors at work that cause expectations about demand to converge among competitors and other interested parties such as customers and security analysts. Nevertheless, the model takes these expectations as a datum.[12] There is little doubt in our minds that a high research priority should be accorded to the problem of how these expectations are determined. While the expectations represent subjective judgments, they are influenced by signals from the environment, by past experience, and by the expectations of others. It is not, therefore, beyond the realm of possibility that the processes that influence the formation of expectations can be subjected to analysis similar to that presented above. Expectations formation would be a function of the actual decisions by competitors embodied in our model, the information content in those decisions, and other signaling behavior of competitors.

The third major area of interest is the effect of uncertainty on the evolution of the industry and on its ultimate structure. Business strategy analysis has emphasized the importance of large shares and of achieving dominant positions by making preemptive investments under the right circumstances. The question of the desirability of dominant shares aside, this leaves unanswered how a firm should go about achieving a dominant share. The analysis above suggests that the presence of exogenous uncertainty makes preemptive investments unattractive. Nevertheless, there may be profitable investment opportunities, contemplated at more modest scales, in markets with high uncertainty.

From an economic standpoint, the effect of uncertainty is to shrink the set of equilibria, eliminating the points characterized by large shares for a few firms. In the absence of uncertainty, the set of equilibria is large.[13] Other considerations, such as who is able to move first or credibly commit themselves to these moves, then determine the outcome from the expanded equilibrium set. One of the effects of uncertainty in the growth phase is thus to reduce the concentration of the mature industry. That in turn can affect the profitability and performance of the industry in other dimensions after the period of rapid growth is over.

The observation that uncertainty reduces the incentive to make preemptive investments raises another research topic. In those markets where uncertainty either is not especially large or is rapidly resolved, the equilibrium analysis does not tell us what will happen. Further analysis of the preemption process is required to determine who will move first, how commitments are made credible, and what signals effectively communicate intentions. Attention to constraints on growth, to the possible advantages of diversified firms with internal financial resources, and to other influential factors will be required.

The high fructose corn syrup problem is not atypical of the expansion problem in general. As with any market, there are some unique features, but the problem is similar to that encountered in many other industries. With a commodity product, the strategic decisions focus upon capacity, scale, and costs. Compared with consumer products or capital goods, the problem is less complicated in that the product policy, marketing, and related decisions are less intricate. Applying this framework to the more complex situations will require careful attention to cross-elasticities of demand and market segmentation. But there seems no reason to expect that the basic approach will be less applicable in these more complex environments.

Appendix A. Financial Implications of Strategic Choices

American Maize

(SCENARIO)

(STRATEGY)			1	2	3	4	5	6
CONVERT	EPDV		105.705500	75.255425	217.756630	182.672950	173.048920	135.495980
	SD		71.981062	65.431276	71.093882	66.468371	89.484487	87.192668
1 MES	PVMAX	1	198.333480	162.297080	349.481220	309.750970	283.889000	245.947760
	PVMIN		4.476020	0.116301	68.503765	38.140455	31.061796	7.117709
	CUMMIN		3.549640	−2.405120	6.220000	6.220000	6.220000	5.220400
1 MES	EPDV		79.635483	29.452691	200.889430	137.700330	160.947510	97.114125
	SD		71.378952	55.959538	65.547177	56.377765	90.911728	82.280129
GREENFIELD	PVMAX	2	167.651350	103.242940	312.710510	242.147750	269.246390	199.005200
	PVMIN		−34.802979	−38.351336	64.695863	15.305580	3.371634	−32.323563
	CUMMIN		−38.057260	−43.119520	−9.780000	−19.560000	−19.667100	−36.565000
3 MES	EPDV		108.821170	48.844504	344.982830	278.217410	276.928860	205.004730
	SD		145.321180	130.863460	159.930710	149.405060	188.716410	183.418720
	PVMAX	3	289.143670	217.614600	642.741430	564.714320	492.296260	420.162360
	PVMIN		−116.096120	−126.003580	14.790971	−46.728548	−63.009955	−108.882100
	CUMMIN		−129.340860	−143.635140	−27.780000	−104.274800	−105.774200	−125.135400
1 MES Add-on	EPDV		92.999119	42.816327	214.253070	151.063970	174.311150	110.477760
	SD		71.378952	55.959538	65.547176	56.377765	90.911727	82.280129
	PVMAX	4	181.014980	116.606570	326.074140	255.511390	282.610020	212.368840
	PVMIN		−21.439344	−24.987700	78.059499	28.669217	16.735271	−18.959928
	CUMMIN		−24.057260	−29.119520	−2.780000	−5.560000	−5.667100	−22.565000
2 MES	EPDV		98.606624	43.158096	287.353180	221.269520	229.517370	161.243990
	SD		108.673140	93.723911	117.969270	108.016980	146.598950	139.777450
	PVMAX	5	233.278700	164.941160	501.784850	426.383520	402.278100	330.647990
	PVMIN		−71.462323	−78.559036	45.627756	−10.933550	−25.351020	−66.503490
	CUMMIN		−77.334520	−87.459041	−27.780000	−55.560000	−55.774200	−74.350000
DO NOTHING	EPDV		74.027977	29.110922	127.789320	67.494781	105.741290	46.347896
	SD		34.371860	18.930135	16.805031	6.898354	36.015186	25.834557
	PVMAX	6	115.387630	54.908348	136.999800	71.275620	149.578310	80.726044
	PVMIN		15.220000	15.220000	97.127604	54.908348	45.457924	15.220000
	CUMMIN		15.220000	15.220000	15.220000	15.220000	15.220000	15.220000

Anheuser-Busch
(SCENARIO)

(STRATEGY)			1	2	3	4	5	6
	1	EPDV	62.514403	58.270865	143.198860	143.293600	111.354920	108.454630
		SD	52.434287	54.702539	64.383616	63.935645	69.046122	72.568240
		PVMAX	131.011400	130.261200	269.549670	268.165710	196.618600	198.848730
		PVMIN	−4.403980	−8.763699	11.835360	6.104573	4.539695	−1.762291
		CUMMIN	−5.330360	−11.285120	−2.660000	−2.660000	−2.660000	−3.659600
	2	EPDV	36.444388	12.468132	126.331670	98.320985	99.253515	70.072778
		SD	51.501729	45.358345	57.935739	58.624499	70.379729	67.839882
		PVMAX	100.329260	71.207054	232.778960	200.562500	181.975990	151.906170
		PVMIN	−43.682980	−47.231337	8.027456	−16.730301	−23.150466	−41.203563
		CUMMIN	−46.937260	−51.999521	−18.660000	−37.320000	−37.427100	−45.445000
	3	EPDV	65.630073	31.859945	270.425060	238.838070	215.234870	177.963380
		SD	125.585240	120.464170	152.998070	146.857840	168.608380	169.451060
		PVMAX	221.821580	185.578720	562.809880	523.129080	405.025860	373.063330
		PVMIN	−124.976110	−134.883580	−41.877433	−78.764428	−89.532055	−117.762100
		CUMMIN	−138.220860	−152.515140	−36.660000	−122.034800	−123.534200	−134.015400
	4	EPDV	49.808025	25.831768	139.695310	111.684620	112.617150	83.436415
		SD	51.501729	45.358345	57.935739	53.624499	70.379729	67.839882
		PVMAX	113.692900	84.570691	246.142590	213.926140	195.339630	165.269800
		PVMIN	−30.319344	−33.867700	21.391093	−3.366665	−9.786830	−27.839928
		CUMMIN	−32.937260	−37.999520	−11.660000	−23.320000	−23.427100	−31.445000
	5	EPDV	55.415530	26.173537	212.795420	181.890170	167.823370	134.202640
		SD	88.888815	83.259592	110.771790	105.362550	126.253730	125.514170
		PVMAX	165.956620	132.905280	421.853300	384.798270	315.007700	283.548960
		PVMIN	−80.342323	−87.439037	−11.040650	−42.969431	−51.873119	−75.383491
		CUMMIN	−86.214520	−96.339040	−36.660000	−73.320000	−73.534200	−83.230000
	6	EPDV	30.836884	12.126363	54.231557	28.115434	44.047292	19.306548
		SD	14.317845	7.885483	7.000256	2.873559	15.002383	10.761570
		PVMAX	48.065542	22.872465	57.068247	29.690370	62.307917	33.627011
		PVMIN	6.340000	6.340000	40.459199	22.872465	18.935824	6.340000
		CUMMIN	6.340000	6.340000	6.340000	6.340000	6.340000	6.340000

Archer-Daniels-Midland

(SCENARIO)

(STRATEGY)		1	2	3	4	5	6
EPDV		124.188170	82.523592	249.661980	199.524470	199.449500	147.067720
SD		80.422020	70.052410	74.176192	67.596433	98.304666	93.494411
PVMAX	1	227.142480	176.006130	383.686160	327.546450	321.234440	266.102750
PVMIN		8.276020	3.916301	92.753758	51.849504	42.411343	10.917709
CUMMIN		7.849640	1.394880	10.020000	10.020000	10.020000	9.020400
EPDV		98.118158	36.720858	232.794780	154.551850	187.348100	108.685870
SD		79.911966	60.544544	68.973741	57.601696	99.759135	88.523990
PVMAX	2	196.460350	116.951990	346.915450	259.943240	306.591820	219.160190
PVMIN		−31.002980	−34.551336	88.945856	29.014630	14.721182	−28.523564
CUMMIN		−34.257259	−39.319520	−5.980000	−11.960000	−12.067100	−32.765000
EPDV		127.303840	56.112671	376.888180	295.068940	303.329450	216.576480
SD		153.791890	135.344850	162.987520	150.514800	197.378800	189.447650
PVMAX	3	317.952670	231.323640	676.946370	582.509830	529.641700	440.317350
PVMIN		−112.296110	−122.203580	39.040964	−33.019500	−51.660408	−105.082100
CUMMIN		−125.540860	−139.835140	−23.980000	−96.674800	−98.174200	−121.335400
EPDV		111.481800	50.084494	246.158420	167.915490	200.711730	122.049510
SD		79.911966	60.544544	68.973741	57.601696	99.759135	88.523990
PVMAX	4	209.823990	130.315620	360.279090	273.306880	319.955460	232.523830
PVMIN		−17.639344	−21.187699	102.309490	42.378266	28.084819	−15.159928
CUMMIN		−20.257260	−25.319520	1.020000	1.020000	1.020000	−18.765000
EPDV		117.089300	50.426263	319.258530	238.121040	255.917960	172.815740
SD		117.167420	98.240712	121.161120	109.178500	155.359550	145.930850
PVMAX	5	262.087710	178.650210	535.989800	444.179010	439.623540	350.802990
PVMIN		−67.662323	−74.759036	69.877749	2.775499	−14.001472	−62.703491
CUMMIN		−73.534520	−83.659040	−23.980000	−47.960000	−48.174200	−70.550000
EPDV		92.510653	36.379089	159.694670	84.346302	132.141880	57.919643
SD		42.953534	23.656451	21.000168	8.620676	45.007151	32.284709
PVMAX	6	144.196630	68.617396	171.204740	89.071110	186.923750	100.881030
PVMIN		19.020000	19.020000	121.377600	68.617396	56.807472	19.020000
CUMMIN		19.020000	19.020000	19.020000	19.020000	19.020000	19.020000

Cargill

(SCENARIO)

(STRATEGY)		1	2	3	4	5	6
EPDV		147.729260	91.780942	290.299320	220.987990	233.075510	161.806480
SD		91.211169	75.957018	78.252175	69.068748	109.579230	101.547830
PVMAX	1	263.836050	193.467130	427.252460	350.212290	368.800740	291.773850
PVMIN		13.116021	8.756301	123.640590	69.310502	56.867084	15.757709
CUMMIN		12.189640	6.234880	14.860000	14.860000	14.860000	13.860400
EPDV		121.659250	45.978207	273.432130	176.015370	220.974110	123.424630
SD		90.793614	66.413087	73.453767	59.196527	111.061570	96.515990
PVMAX	2	233.153920	134.412980	390.481750	282.609080	354.158120	244.831290
PVMIN		−26.162980	−29.711336	119.832690	46.475628	29.176921	−23.683565
CUMMIN		−29.417261	−34.479521	−1.140000	−2.280000	−2.387100	−27.925001
EPDV		150.844930	65.370021	417.525520	316.532450	336.955460	213.315230
SD		164.597540	141.075880	166.952590	151.944790	208.452370	197.165210
PVMAX	3	354.646240	248.784650	720.512680	605.175660	577.207990	465.988450
PVMIN		−107.456110	−117.363580	69.927797	−15.558501	−37.204669	−100.242100
CUMMIN		−120.700860	−134.995140	−19.140000	−86.994802	−88.494201	−116.495400
EPDV		135.022890	59.341844	286.795760	189.379010	234.337740	136.788260
SD		90.793615	66.413087	73.453767	59.196526	111.061570	96.515992
PVMAX	4	246.517560	147.776620	403.845390	295.972710	367.521760	258.194920
PVMIN		−12.799344	−16.347700	133.196330	59.839265	42.540558	−10.319928
CUMMIN		−15.417261	−20.479521	5.860000	5.860000	5.860000	−13.925001
EPDV		140.630390	59.683611	359.895870	259.584560	289.543960	187.554490
SD		128.003340	104.020650	125.312240	110.679070	166.553500	153.803540
PVMAX	5	298.781280	196.111210	579.556090	466.844840	487.189830	376.474080
PVMIN		−62.822324	−69.919037	100.764580	20.236498	0.454267	−57.863493
CUMMIN		−68.694520	−78.819042	−19.140000	−38.280000	−38.494200	−65.710000
EPDV		116.051740	45.636438	200.332010	105.809820	165.767880	72.658396
SD		53.883875	29.676283	26.344810	10.814371	56.460073	40.500165
PVMAX	6	180.890190	86.078395	214.771040	111.736940	234.490050	126.552130
PVMIN		23.860000	23.860000	152.264430	86.078395	71.263211	23.860000
CUMMIN		23.860000	23.860000	23.860000	23.860000	23.860000	23.860000

CPC International

(SCENARIO)

(STRATEGY)		1	2	3	4	5	6
EPDV		366.213940	177.698330	667.454130	420.190720	545.158220	298.596720
SD		192.108270	131.258010	120.891100	84.244514	215.119260	177.003520
PVMAX	1	604.388760	355.522520	831.590900	560.573720	810.263140	530.027060
PVMIN		58.036022	58.676301	410.301040	231.365890	191.030680	60.677711
CUMMIN		57.109642	51.154881	59.780001	59.780001	59.780001	58.780401
EPDV		340.143920	131.895600	650.586940	375.218110	533.056820	260.214870
SD		192.050130	121.586790	118.500960	75.446725	216.714550	171.698970
PVMAX	2	573.706630	296.468380	794.820180	492.970500	795.620530	483.084500
PVMIN		18.757021	15.208665	406.493140	208.531020	163.340520	21.236437
CUMMIN		15.502740	10.440481	43.780001	43.780001	43.780001	16.995001
EPDV		369.329610	151.287410	794.680340	515.735180	649.038170	368.105470
SD		265.372410	195.097160	206.736310	166.013740	312.533290	270.196210
PVMAX	3	695.198940	410.840030	1124.851100	815.537080	1018.670400	704.241660
PVMIN		−62.536112	−72.443578	356.588250	146.496890	96.958935	−55.322096
CUMMIN		−75.780858	−90.075141	25.780001	2.845201	1.345802	−71.575399
EPDV		353.507560	145.259230	663.950580	388.581740	546.420460	273.578510
SD		192.050130	121.586790	118.500960	75.446725	216.714550	171.698970
PVMAX	4	587.070260	309.832010	808.183820	506.334140	808.984170	496.448140
PVMIN		32.120656	28.572301	419.856780	221.894660	176.704160	34.600074
CUMMIN		29.502740	24.440481	50.780001	50.780001	50.780001	30.995001
EPDV		359.115070	145.601000	737.050700	458.787300	601.626680	324.344740
SD		228.999980	158.518470	167.104560	125.582430	271.477090	228.026660
PVMAX	5	639.333980	358.166600	983.894540	677.206280	928.652240	614.727300
PVMIN		−17.902321	−24.999035	387.425030	182.291890	134.617870	−12.943491
CUMMIN		−23.774518	−33.899039	25.780001	25.780001	25.780001	−20.789999
EPDV		334.536420	131.853830	577.486830	305.012550	477.850600	209.448640
SD		155.328290	85.546303	75.942837	31.174032	162.754560	116.747750
PVMAX	6	521.442910	248.133790	619.109470	322.098370	675.952450	364.805340
PVMIN		68.780001	68.780001	438.924880	248.133790	205.426810	68.780001
CUMMIN		68.780001	68.780001	68.780001	68.780001	68.780001	68.780001

Grain Processing

(SCENARIO)

(STRATEGY)			1	2	3	4	5	6
	EPDV		167.476540	99.546404	324.387660	238.992510	261.282450	174.169980
	SD		100.285160	80.923154	81.784009	70.332795	119.063080	108.322160
	PVMAX	1	294.616190	208.114170	463.797740	369.225360	408.701390	313.307870
	PVMIN		17.176021	12.816301	149.549800	83.957540	68.993179	19.817709
	CUMMIN		16,249640	10.294880	18.920000	18.920000	18.920000	17.920400
	EPDV		141.406530	53.743670	307.520470	194.019890	249.181050	135.788130
	SD		99.929805	71.355315	77.296544	60.563236	120.564440	103.247080
	PVMAX	2	263.934060	149.060020	427.027030	301.622150	394.058770	266.365310
	PVMIN		−22.102980	−25.651335	145.741890	61.122665	41.303017	−19.623564
	CUMMIN		−25.357260	−30.419520	2.920000	2.920000	2.920000	−23.865000
	EPDV		170.592210	73.135485	451.613870	334.536980	365.162400	243.678730
	SD		173.673820	145.901250	170.336800	153.158270	217.771620	203.669080
	PVMAX	3	385.426380	263.431680	757.057960	624.188740	617.108640	487.522460
	PVMIN		−103.396110	−113.303580	95.837002	−0.911463	−25.078573	−96.182096
	CUMMIN		−116.640860	−130.935140	−15.080000	−78.874800	−80.374200	−112.435400
	EPDV		154.770160	67.107307	320.884110	207.383530	262.544680	149.151760
	SD		99.929805	71.355315	77.296544	60.563236	102.564440	103.247080
	PVMAX	4	277.297700	162.423660	440.390670	314.985790	407.422410	279.728940
	PVMIN		−8.739344	−12.287699	159.105530	74.486302	54.666653	−6.259927
	CUMMIN		−11.357260	−16.419520	9.920000	9.920000	9.920000	−9.865000
	EPDV		160.377670	67.449076	393.984220	277.589080	317.750910	199.917990
	SD		137.104530	108.889160	128.862180	111.955450	175.969170	160.434010
	PVMAX	5	329.561420	210.758250	616.101370	485.857920	527.090490	398.008090
	PVMIN		−58.762323	−65.859035	126.673790	34.883535	12.590364	−53.803492
	CUMMIN		−64.634521	−74.759039	−15.080000	−30.160000	−30.374200	−61.650000
	EPDV		135.799020	53.401901	234.420360	123.814340	193.974820	85.021895
	SD		63.052715	34.725977	30.827624	12.654537	66.067278	47.391644
	PVMAX	6	211.670330	100.725430	251.316320	130.750020	274.390700	148.086150
	PVMIN		27.920000	27.920000	178.173630	100.725430	83.389307	27.920000
	CUMMIN		27.920000	27.920000	27.920000	27.920000	27.920000	27.920000

Hubinger

(SCENARIO)

(STRATEGY)			1	2	3	4	5	6
	EPDV		93.351286	70.397228	196.430420	171.409030	155.402210	127.761170
	SD		66.359077	62.351208	69.099026	65.728722	83.609303	82.993167
	PVMAX	1	179.076940	153.133670	326.617920	297.856080	258.926520	232.475740
	PVMIN		1.936020	−2.423699	52.294559	28.977038	23.475519	4.577709
	CUMMIN		1.009640	−4.945120	3.680000	3.680000	3.680000	2.680400
	EPDV		67.281273	24.594494	179.563230	126.436420	143.300810	89.379326
	SD		65.682376	52.908692	63.308449	55.574398	85.014847	78.125295
	PVMAX	2	148.394810	94.079519	289.847200	230.252870	244.283910	185.533180
	PVMIN		−37.342979	−40.891336	48.486656	6.142164	−4.214642	−34.863563
	CUMMIN		−40.597260	−45.659521	−12.320000	−24.640000	−24.747100	−39.105000
	EPDV		96.466956	43.986308	323.656620	266.953500	259.282160	197.269930
	SD		139.666740	127.877840	157.916650	148.669790	182.944030	179.405200
	PVMAX	3	269.877130	208.451180	619.878140	552.819450	467.333780	406.690340
	PVMIN		−118.636120	−128.543580	−1.418235	−55.891964	−70.596231	−111,422100
	CUMMIN		−131.880860	−146.175140	−30.320000	−109.354800	−110.854200	−127.675400
	EPDV		80.644910	37.958131	192.926860	139.800050	156.664440	102.742960
	SD		65.682376	52.908692	63.308451	55.574398	85.014846	78.125295
	PVMAX	4	161.758440	107.443160	303.210840	243.616500	257.647540	198.896810
	PVMIN		−23.979344	−27.527700	61.850292	19.505800	9.148994	−21.499928
	CUMMIN		−26.597260	−31.659520	−5.320000	−10.640000	−10.747100	−25.105000
	EPDV		86.252414	38.299900	266.026980	210.005610	211.870660	153.509190
	SD		103.003460	90.716690	115.871480	107.249000	140.759460	135.679760
	PVMAX	5	214.022160	155.777750	478.921550	414.488640	377.315620	317.175970
	PVMIN		−74.002323	−81.099037	29.418550	−20.096967	−32.937296	−69.043490
	CUMMIN		−79.874520	−89.999042	−30.320000	−60.640000	−60.854200	−76.890000
	EPDV		61.673768	24.252726	106.463110	56.230868	88.094584	38.613096
	SD		28.635689	15.770967	14.000511	5.747118	30.004767	21.523139
	PVMAX	6	96.131084	45.794931	114.136490	59.380740	124.615830	67.254023
	PVMIN		12.680000	12.680000	80.918399	45.744931	37.871648	12.680000
	CUMMIN		12.680000	12.680000	12.680000	12.680000	12.680000	12.680000

National Starch

(SCENARIO)

(STRATEGY)			1	2	3	4	5	6
	EPDV		87.222821	67.987257	185.851280	165.821430	146.648330	123.924230
	SD		63.577790	60.826310	68.130616	65.366228	80.702233	80.914318
	PVMAX	1	169.524480	148.588040	315.276280	291.955470	246.543560	225.792770
	PVMIN		0.676021	−3.683699	44.253772	24.431467	19.712248	3.317709
	CUMMIN		−0.250360	−6.205120	2.420000	2.420000	2.420000	1.420400
	EPDV		61.152808	22.184524	168.984080	120.848810	134.546930	85.542378
	SD		62.859189	51.400138	62.214921	55.180451	82.095735	76.070703
	PVMAX	2	138.842350	89.533889	278.505570	224.352260	231.900950	178.850210
	PVMIN		−38.602979	−42.151336	40.445869	1.596533	−7.977913	−36.123563
	CUMMIN		−41.857259	−46.919520	−13.580000	−27.160000	−27.267100	−40.365000
	EPDV		90.338490	41.576338	313.077480	261.365890	250.528280	193.432980
	SD		136.864300	126.399910	156.926550	148.307020	180.086340	177.419420
	PVMAX	3	260.334670	203.905550	608.536490	546.918840	454.950820	400.007370
	PVMIN		−119.896110	−129.803580	−9.459023	−60.437595	−74.359503	−112.682100
	CUMMIN		−133.140860	−147.435140	−31.580000	−111.874800	−113.374200	−128.935400
	EPDV		74.516444	35.548161	182.347720	134.212450	147.910560	98.906014
	SD		62.859188	51.400138	62.214921	55.180451	82.095734	76.070703
	PVMAX	4	152.205980	102.897530	291.869200	237.715900	245.264580	192.213850
	PVMIN		−25.239343	−28.787699	53.809505	14.960170	5.385724	−22.759928
	CUMMIN		−27.857260	−32.919520	−6.580000	−13.160000	−13.267100	−26.365000
	EPDV		80.123948	35.889929	255.447830	204.418000	203.116790	149.672240
	SD		100.193750	89.228816	114.842030	106.870590	137.868150	133.652040
	PVMAX	5	204.469710	151.232110	467.579910	408.588030	364.932660	310.493000
	PVMIN		−75.262323	−82.359036	21.377763	−24.642598	−36.700567	−70.303491
	CUMMIN		−81.134520	−91.259040	−31.580000	−63.160000	−63.374200	−78.150000
	EPDV		55.545303	21.842755	95.883973	50.643259	79.340706	34.776148
	SD		25.790187	14.203821	12.609293	5.176032	27.023221	19.384405
	PVMAX	6	86.578627	41.199300	102.794860	53.480131	12.232870	60.571053
	PVMIN		11.420000	11.420000	72.877612	41.199300	34.108378	11.420000
	CUMMIN		11.420000	11.420000	11.420000	11.420000	11.420000	11.420000

Pennick & Ford

(SCENARIO)

	(STRATEGY)	1	2	3	4	5	6
EPDV		111.931240	77.703650	228.503690	188.349250	181.941750	139.393830
SD		74.820756	66.986230	72.119586	66.845519	92.451797	89.312994
PVMAX	1	208.037570	166.914870	361.002890	315.745230	296.468510	252.736810
PVMIN		5.756020	1.396301	76.672184	42.758240	34.884801	8.397709
CUMMIN		4.829640	−1.125120	7.500000	7.500000	7.500000	6.500400
EPDV		85.861226	31.900916	211.636500	143.376630	169.840340	101.011980
SD		74.251978	57.501405	66.691570	56.787148	93.888838	84.379858
PVMAX	2	177.355430	107.860720	324.232170	248.142020	281.825900	205.794250
PVMIN		−33.522979	−37.071336	72.864282	19.923366	7.194640	−31.043564
CUMMIN		−36.777259	−41.839520	−8.500000	−17.000000	−17.107100	−35.285000
EPDV		115.046910	51.292730	355.729900	283.893710	285.821700	208.902580
SD		148.173050	132.371080	160.954650	149.777580	191.630880	185.446360
PVMAX	3	298.847760	222.232380	654.263110	570.708600	504.875780	426.951410
PVMIN		−114.816110	−124.723580	22.959390	−42.110763	−59.186949	−107.602100
CUMMIN		−128.060860	−142.355140	−26.500000	−101.714800	−103.214200	−123.855400
EPDV		99.224862	45.264552	225.000140	156.740270	183.203980	114.375610
SD		74.251978	57.501405	66.691571	56.787148	93.888838	84.379859
PVMAX	4	190.719070	121.224360	337.595810	261.505660	295.189540	219.157890
PVMIN		−20.159343	−23.707699	86.227918	33.287003	20.558277	−17.679928
CUMMIN		−22.777260	−27.839520	−1.500000	−3.000000	−3.107100	−21.285000
EPDV		104.832370	45.606320	298.100250	226.945820	238.410200	165.141840
SD		111.532880	95.243089	119.037460	108.406566	149.546820	141.847230
PVMAX	5	242.982790	169.558950	513.306530	432.377790	414.857610	337.437040
PVMIN		−70.182323	−77.279037	53.796175	−6.315765	−21.528014	−65.223491
CUMMIN		−76.054520	−86.179040	−26.500000	−53.000000	−53.214200	−73.070000
EPDV		80.253720	31.559146	138.536390	73.171082	114.634120	50.245748
SD		37.262529	20.522157	18.218331	7.478505	39.044057	28.007240
PVMAX	6	125.091710	59.526133	148.521460	77.269891	162.157830	87.515093
PVMIN		16.500000	16.500000	105.296020	59.526133	49.280931	16.500000
CUMMIN		16.500000	16.500000	16.500000	16.500000	16.500000	16.500000

Staley

(SCENARIO)

	(STRATEGY)	1	2	3	4	5	6
EPDV		287.418790	178.898830	533.599920	396.963190	435.565940	296.300640
SD		161.952080	130.500320	135.220580	117.298450	191.729960	174.269260
PVMAX	1	491.218180	352.844080	766.398440	615.136910	671.145320	518.426160
PVMIN		30.699001	23.896862	241.852070	137.131910	113.251070	34.820627
CUMMIN		29.253640	19.962880	33.420000	33.420000	33.420000	31.860400
EPDV		261.348770	133.096100	516.732730	351.990570	423.464540	257.918790
SD		161.585750	120.990210	130.304350	107.357240	193.212330	169.231660
PVMAX	2	460.536050	293.789930	729.627720	547.533690	656.502700	471.483600
PVMIN		−8.580000	−14.570775	238.044170	144.297040	85.560905	−4.620646
CUMMIN		−12.353260	−20.751520	17.420000	17.420000	17.420000	−9.925000
EPDV		290.534460	152.487910	660.826130	492.507660	539.445890	365.809390
SD		235.431390	195.541900	223.789350	200.142680	290.332780	269.442500
PVMAX	3	582.028380	408.161590	1059.658600	870.100270	879.552570	692.640760
PVMIN		−89.873132	−102.223020	188.139280	52.262909	19.179316	−81.179179
CUMMIN		−103.636860	−121.267140	−0.580000	−49.834800	−51.494201	−98.495400
EPDV		274.712410	146.459730	530.096370	365.354220	436.828180	271.282430
SD		161.585750	120.990210	130.304350	107.357240	193.212330	169.231660
PVMAX	4	473.899680	307.153570	742.991360	560.897330	669.866340	484.847240
PVMIN		4.783637	−1.207139	251.407800	127.660670	98.924542	8.742991
CUMMIN		1.646740	−6.751520	24.420000	24.420000	24.420000	4.075000
EPDV		280.319920	146.801500	603.196480	435.559760	492.034400	322.048660
SD		198.837600	158.560910	182.260750	158.898120	248.677670	226.416470
PVMAX	5	526.163410	355.488160	918.702070	731.769470	789.534420	603.126400
PVMIN		−45.239343	−54.778475	218.976060	88.057907	56.838252	−38.800572
CUMMIN		−51.630520	−65.091040	−0.580000	−1.480000	−1.494200	−47.710000
EPDV		255.741270	132.754330	443.632620	281.785030	368.258320	207.152560
SD		124.438280	83.757279	79.660269	56.221810	138.129970	112.602890
PVMAX	6	408.272330	245.455340	553.917010	376.661560	536.834630	353.204440
PVMIN		41.442980	39.000561	270.475910	153.899810	127.647200	42.922918
CUMMIN		40.924000	37.588000	42.420000	42.420000	42.420000	41.860000

Standard Brands
(SCENARIO)

(STRATEGY)		1	2	3	4	5	6
EPDV		207.165070	147.339680	395.063540	323.792110	320.931820	246.054900
SD		125.181110	110.510440	121.406250	112.322870	153.398180	146.959410
PVMAX	1	366.126480	293.317940	617.876980	537.867020	508.987490	430.911070
PVMIN		14.199001	7.396861	136.556050	77.605779	63.970138	18.320627
CUMMIN		12.753641	3.462880	16.920000	16.920000	16.920000	15.360400
EPDV		181.095050	101.536950	378.196340	278.819490	308.830420	207.673040
SD		124.627740	101.093840	115.658460	102.147020	154.818350	142.056320
PVMAX	2	335.444340	234.263800	581.106260	470.263800	494.344880	383.968510
PVMIN		−25.079999	−31.070776	132.748150	54.770905	36.279975	−21.120646
CUMMIN		−28.853261	−37.251521	0.920000	0.920000	0.920000	−26.425000
EPDV		210.280740	120.928760	522.289740	419.336580	424.811770	315.563650
SD		198.630280	175.946980	210.225380	195.258990	252.455000	242.919070
PVMAX	3	456.936660	348.635460	911.137200	792.830380	717.394740	605.125670
PVMIN		−106.373130	−118.723020	82.843254	−7.263224	−30.101615	−97.679179
CUMMIN		−120.136860	−137.767140	−17.080000	−82.834800	−84.494201	−114.995400
EPDV		194.458690	114.900590	391.559980	292.183130	322.194050	221.036680
SD		124.627750	101.093840	115.658460	102.147020	154.818350	142.056320
PVMAX	4	348.807980	247.627430	594.469900	483.627440	507.708510	397.332150
PVMIN		−11.716363	−17.707139	146.111780	68.134542	49.643612	−7.757009
CUMMIN		−14.853260	−23.251520	7.920000	7.920000	7.920000	−12.425000
EPDV		200.066190	115.242360	464.660090	362.388680	377.400280	271.802910
SD		161,970160	138.843200	168.237710	153.842040	210.515690	199.504560
PVMAX	5	401.071700	295.962020	770.180600	654.499570	627.376590	515.611310
PVMIN		−61.739343	−71.278475	113.680040	28.531775	7.557322	−55.300572
CUMMIN		−68.130520	−81.591040	−17.080000	−34.480000	−34.494200	−64.209999
EPDV		175.487550	101.195180	305.096230	208.613950	253.624200	156.906810
SD		87.356640	63.577345	63.687723	50.586615	99.393394	84.988533
PVMAX	6	283.180620	185.929210	405.395550	299.391670	374.676800	265.689350
PVMIN		24.942981	22.500561	165.179890	94.373672	78.366266	26.422918
CUMMIN		24.424000	21.088000	25.920000	25.920000	25.920000	25.360000

Appendix B. Summary of Considerations in Predicting Individual Firm Decisions

American Maize. This company is committed to the corn milling industry because of long participation and the background of top management. It cannot withstand very large negative cumulative cash flows, but it will want to participate in the HFCS market. American Maize is one of the older CWM companies that had been damaged by the entry into CWM of Cargill and Archer-Daniels-Midland, both of which entered with large, efficient operations.

Anheuser-Busch. Primarily a beer company, AB developed its own enzyme technology for HFCS production. It will enter if the opportunity is right. The financial resources are large enough to absorb risk, but AB is far from committed to CWM. The AB corn milling operation reports to a Busch executive also responsible for the St. Louis Cardinals and Busch Gardens, other AB operations. Busch has been in corn milling primarily as a by-product of technological capability drawn from its brewing operations.

Archer-Daniels-Midland. A closely held company with large financial resources, ADM had successfully entered CWM in 1970–71. The company's experience is in agricultural commodities, and it is used to low margins and wide earnings swings, and to surviving through competing with large, highly efficient facilities. ADM can absorb risk and is known as a risk taking company. Short-run dips in stock prices are of less concern to ADM than to less closely held firms. ADM was likely to invest heavily, as it had in basic CWM in 1970–71.

Cargill. Cargill is an extremely large, privately held, very successful grain trading company that was diversifying into other commodity products much like ADM. Cargill has much in common with ADM: it is a risk taker, it has significant financial resources, it is experienced with cyclical commodities, and it is used to competing on cost and scale. Our feeling is that Cargill is slightly more conservative in taking risks than ADM.

CPC International. Long the historical leader in CWM, CPC had relinquished a substantial share of the market by 1972. Managerial and financial resources had been devoted to a successful program of international expansion and diversification into consumer products. CPC had the financial resources to compete vigorously in HFCS, was very conservatively managed, and was attempting to achieve steady growth in sales and earnings. In 1972, HFCS was likely to appear too risky to justify a major commitment of resources. CPC therefore would enter tentatively and in a small way.

Grain Processing. This is a privately held company with a history similar to that of ADM and Cargill. We know very little about GP, and hence their behavior is hard to predict. They entered CWM in the mid-sixties before Cargill and ADM. That entry seemed less aggressive than the later moves by Cargill and ADM.

Hubinger. Hubinger is a small old-line corn wet miller. It is totally dependent on CWM and in financial difficulty as a result of the price wars accompanying ADM's entry into CWM in 1970–71. Hubinger will want to participate in HFCS, but with limited financial resources could not mount a major effort. At most they would be likely to convert. As a matter of history the H. J. Heinz Company bought Hubinger in 1975 (having failed in a bid to acquire Staley), and with Heinz's considerable resources, Hubinger did move into HFCS in 1976.

National Starch. This company is a relatively small, enormously successful specialty starch and adhesives company whose strategy consists of R&D and product differentiation. NS has consistently avoided undifferentiated commodities and the need for high volume, low cost operations by producing only specialty starches among CWM products. NS is well managed and would not regard HFCS as either a threat or an appropriate opportunity. It was the least vulnerable of any firm to excess capacity in the traditional HFCS markets.

Pennick & Ford. A relatively small old-line CWM company, P&F, like Hubinger, was hurt by the ADM entry. P&F was purchased by R. J Reynolds in the mid-1960s and then sold under Federal Trade Commission pressure to VWR Corporation. VWR was experiencing profitability problems, and the P&F operation was losing money in 1972. P&F could want to play the HFCS game, but lacked the financial resources for a large, risky commitment and perhaps even for a modest commitment.

Staley. Staley was a major participant in CWM and the only firm to license the HFCS technology from Standard Brands before 1972. In 1972, Staley had 200 million pounds of HFCS capacity on-stream, about the same as Standard Brands. Staley is heavily committed to HFCS and possesses significant financial resources. But a very large investment in HFCS may strain Staley's financial situation depending upon how the HFCS market develops.

Standard Brands. SB is a diversified consumer food products company. It purchased Japanese technology for HFCS production and pioneered the commercial introduction of HFCS in the United States. SB had significant financial resources and is not heavily dependent on CWM. It like CPC had turned its attention away from corn wet milling into other businesses in recent years and offered to license the technology to any firm that wanted it. Its initial strategy seemed to be to encourage development of the HFCS market while aggressively leading the development. Thus, it will probably invest, but not attempt to preempt the market.

As a matter of historical record, Amstar, the largest sugar refiner in the United States, also entered HFCS, to hedge against the obvious threat HFCS presented to the traditional sugar markets. It was believed, and still is to some extent, that HFCS is, in the long run, at least as inexpensive a liquid sweetener as sugar and is probably lower in cost than sugar.

Notes

1. All data used in this paper are taken from Michael E. Porter and Margaret Lawrence, *Note on the Corn Wet Milling Industry in 1972* (Intercollegiate Case Clearinghouse, Boston, 1978, Case 1-378-186, and *Note on the Corn Wet Milling Industry, 1973–1977* (Intercollegiate Case Clearinghouse, Boston, 1978, Case 1-378-206).

2. The industry also produced other products, including dextrose and dextrins. They are not nearly so important as starch and corn syrup, and are omitted from the discussion for simplicity.

3. This Nash equilibrium concept has been criticized in static models on the grounds that it involves mistaken assumptions about rivals' behavior. The point there is that an oligopoly game is played repeatedly or continuously. This creates a situation in which learning about rivals' behavior can occur and behavior can adapt. However, the capacity expansion game is played once. The issue of whether to assume firms will continue doing what they are doing now (a poor assumption in the pricing problem) does not arise here. In the capacity expansion situation, the problem for the firm is to avoid errors about rivals' behavior. That, we argue, involves finding a pairing of individual firm choices and aggregate outcomes that is internally consistent.

4. All demand figures are taken from United States Department of Agriculture *Sugar and Sweetener Reports*.

5. More precisely, this involves making the following approximation: Our interest will be in the mean and variance of the present value of net cash flows. Since the cash flow in period t depends on sugar price in period t, the expected value or mean of the present value is not affected by our implicit assumption that sugar prices are perfectly correlated over time. The variance, however, is affected. Let $Vt(pt)$ be the discounted present value of the derivation of the cash flow in period t, as a function of the sugar price in period t. The variance of the present value of net cash flows is

$$V = \sum_{\tau,t=1}^{T} E(Vt(pt)V\tau(p\tau)).$$

Taking a linear approximation $Vt(pt) = Vt'(\bar{p})(pt - \bar{p})$,

$$V = \sum_{\tau,t=1}^{T} Vt'(\bar{p})V\tau'(\bar{p})\,\mathrm{cov}\,(pt,p\tau).$$

What we did is set $pt = p$, a random variable. Thus, our calculated variance is

$$\hat{V} = \sum_{\tau,t=1}^{T} Vt'(\bar{p})V\tau'(\bar{p})\,\mathrm{var}\,(p).$$

Letting $s\tau t$ be the correlation coefficient for pt and $p\tau$,

$$V = \sum_{s;t=1}^{T} Vt'(\bar{p})V\tau'(\bar{p})s t\tau\,\mathrm{var}(p).$$

Thus, $\hat{V}$, the measure we used, overstates the variance of the present value of cash flows by an amount that depends inversely on the closeness of the serial correlation $\hat{V}$ and V. With no serial correlation, all the terms in V with $t \neq \tau$ are zero. With more time and a larger budget one would want to estimate an autoregressive model for sugar prices and use that in calculating V. But that was not done here. The result is an overstatement of the variance of present value of net cash flows.

6. Making capacity expansion adapt to demand is in lieu of a full dynamic programming treatment in which one would work backward from future to present decisions.

7. We have ignored for simplicity the option of adding corn syrup and HFCS refining capacity to existing grind capacity.

8. We recall that the specific assumptions about HFCS demand are as follows: (*a*) In the long run, liquid sugar and HFCS are close substitutes, and as a result HFCS will be priced close to sugar. (*b*) Demand for HFCS is also a function of industry capacity. (*c*) In the short and medium term, HFCS demand may be substantially below its long-run equilibrium level, because of changeover costs and possible taste effects for bottlers.

9. *Business Week*, 15 November 1976.

10. For a listing of the announced capacity decisions, see "Note on the Corn Wet Milling Industry, 1973–1977," Harvard Business School, Case 1-376-206.

11. One might interpret the preemptive investment prescription in a different way. Admitting that uncertainty may make such a strategy unacceptably risky to a single firm, one could use it as a screening device: put resources preemptively into markets where the risks are not imprudently high. Or more bluntly, do not play risky competitive games. Whether that is good advice depends upon the menu of investment opportunities that are open to the firm. It has the luxury of choosing among low risk, high return investments; few would argue that it should accept the risks involved in markets like HFCS, but not all firms have this option.

12. The model takes expectations about demand as exogenous. Expectations about capacity expansion and competitor behavior are endogenous, and emerge from the equilibrium analysis.

13. This problem of large numbers of equilibria is reminiscent of the oligopoly problem in the mature industry, where reasonable concepts of equilibrium do not delimit the outcomes sufficiently for predictive purposes.

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Comment Sidney G. Winter

There are clearly good reasons to regard the Porter and Spence paper as being in a different genre from the others presented at this conference—for example, the others say very little about corn syrup.

At a higher level of abstraction also, the paper has a unique orientation. In my comments, I want to view the paper in perspective from a high level of theoretical generality, and in so doing to emphasize some of its distinctive features more than the authors themselves have done. The "perspective" I offer is not a critical one, for I find myself much in sympathy with the sort of inquiry that Porter and Spence have undertaken. Their willingness to plunge into the detail of a specific industry in a specific historical setting and to organize that detail in a coherent theoretical framework seems to me quite laudable. The resulting analysis illuminates not merely the specific situation studied, but also the broad and fundamental problem of the role of prices and markets in coordinating activity. On the other hand, I am skeptical about some details of their approach. In the final section of my comment, I suggest an alternative view of how oligopolists might succeed in coordinating their investment behavior in the sort of situation they describe.

In his 1968 presidential address to the Econometric Society, F. H. Hahn reviewed some basic problems in analysis of the adjustment dynamics of market systems. He closed with an elegant and concise statement of our central theoretical task: "The most intellectually exciting question of our subject remains: is it true that the pursuit of private interest produces not chaos but coherence, and if so, how is it done?" (Hahn 1970, p. 12). To study economic dynamics is, of course, to appreciate the particular importance of the query, *How is it done*? The result of Hahn's survey was a rather gloomy appraisal of the progress that economic theorists had made in understanding the mechanism of the "invisible hand": "I see no support for the view that any of the traditional methods of response of various agents to their economic environment makes the 'hand' perform as it is often taken to perform." (Hahn 1970, p. 1).

Although there have been many important advances in economic theory since Hahn's address, a similar survey today would no doubt reach much the same conclusion. Progress toward understanding the active coordinating function of the market mechanism has been minimal. This is a consequence of the overwhelmingly dominant role of equilibrium analysis in the research method of most economic theorists. As practiced by economists, equilibrium analysis involves the application of consistency tests to limit the range of situations that are regarded as actually realizable in economic life. The great power of the method lies precisely

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in the fact that it obviates the need to study the complicated and probably situation-specific dynamic processes by which "inconsistencies" in the system are identified and eliminated. However, it is hardly surprising that economists remain uninformed about the answers to questions they have chosen to suppress. The question, *How is it done*? remains largely unanswered because it remains largely unexplored.

That equilibrium analysis, as usually practiced, fails to illuminate disequilibrium processes is inherent in the logic of the method. That the failure is an important one—perhaps so important as ultimately to force the sacrifice of the great simplifications the method yields—is a feature of economic reality. More specifically, the importance of the failure can be attributed to the following four features of reality, taken singly and in combination.

—Futures markets and contingent markets exist only in negligible proportion to the scope envisaged for these institutional devices in abstract models of efficient intertemporal allocation under uncertainty.
—The institutional reality does not include a *tatônnement*; more broadly, it includes no device for systematically checking the consistency of tentative plans formulated by a large fraction of economic actors *before* actual implementation of those plans has begun.
—The existence of specialized producers' durables and the cost conditions characteristic of processes of information acquisition, transfer, and storage contribute an important degree of irreversibility to many economic decisions; i.e., with all prices held constant there are large present value sacrifices involved in reverting to an initial state after having taken certain sorts of actions.
—Technological change continually generates new, imperfectly anticipated allocational possibilities, and at the same time destroys the viability of old allocations; more broadly, such processes of long-term historical change as population growth, industrialization, resource depletion, waste accumulation, and naturally occurring climatic change all combine with advancing technology to present a continually novel context for all economic choice.

But for the first two considerations, the market mechanism would in fact be the sort of planning system to which economists often compare it. Currently functioning markets would signal the future consequences of proposed current action, conditioned by the proposed current actions of others. But in fact, it is overwhelmingly the case that it is steps actually *taken* by each actor that impinge on the others, not steps *contemplated*. And the implications of steps actually taken may remain latent and obscured for a long time, before they affect prices in a functioning market. Such a system does not necessarily produce "chaos," but to represent it as a system that checks plans for mutual consistency is to employ a loose and misleading metaphor.

Were it not for the third consideration, the consequences of imperfect coordination would be ephemeral, and the distinction between consistency testing of plans and consistency testing of actual actions would evaporate. As inconsistencies appeared, revealing some past choices as mistaken, there would be quick reversals and redirections of action. The stability properties of such a multiactor, frictionless quest for a consistent solution are problematic, but at least the social learning process would not be complicated and slowed by the accumulating, slowly depreciating "debris of the actual groping process" (Hahn 1970, p. 4). As it is, the actor who has made an economically irreversible mistake has presumably learned something about the problem he faced, but he now faces a new problem. And the actor who has somehow stumbled on the (or "an") equilibrium action will fail to find corroboration of his choice as the durable consequences of the mistaken choices of others shape his environment.

Finally, the reality of nonrepetitive historical change mocks the equilibrium theorist's last-resort comforting thought, the proposition that, if the problem stands still, the social learning process will surely find the right answer to it. Given enough time, even slow learners making slowly depreciating mistakes should be able to grope their way to a solution. Again, acceptance of this hypothetical proposition is qualified by concerns about the stability of the adjustment process; also, information cost considerations provide reason to doubt the supposition that the accumulation of sufficient experience is the only requisite of perfect learning. But the important point is that these sorts of questions arise only in models. In reality, the problem is not standing still at all.

I should emphasize that the foregoing considerations do not directly imply any judgment on the merits of market mechanisms and the pursuit of private interest as against any concrete organizational alternative for dealing with the social coordination problem. The invisible hand has many strengths, and in many contexts those strengths may confer a decisive superiority relative to other arrangements. Rather, the judgment is about the adequacy of equilibrium analysis in the neo-Walrasian tradition, and it is one of skepticism about the ability of that sort of analysis to reveal the true character of the institutional arrangements it purports to analyze. The insights of Hayek (1948) and Schumpeter (1950), though admittedly undeveloped by contemporary standards, may have a more direct bearing on the "most intellectually exciting question of our subject" than the modern theorist's storehouse full of existence and optimality results.

Now consider, from this point of view, the situation in the corn wet milling industry that Porter and Spence describe. A technological advance—the development of a commercially viable production method for high fructose corn syrup—faced the firms of the industry with a novel decision context. The market for their products had expanded in a relatively *unanticipated and discontinuous* manner, an aspect of the situation underemphasized by the title of the Porter and Spence paper. It was clear that the new product represented a profit opportunity, but the size of the market would ultimately depend on the degree to which HFCS could displace sugar in various applications. Also, and fundamentally, it was not at all clear to whom the profit opportunity "belonged." If all firms were to respond aggressively by adding new capacity to produce HFCS, they might all regret it—even in the event of strong demand. On the other hand, very timid responses all around would mean high profits per unit, but low total profit. Thus, from the point of view of industry profitability, and of course also from a social welfare point of view, a significant coordination problem existed. By making investment decisions without a proper allowance for the contemporaneous actions of others, firms could easily sacrifice profits and waste resources. Overresponse in particular posed the threat of prolonged overcapacity not just in HFCS, but in all markets involving the same upstream processes. (The standard of a "proper allowance" for the actions of others depends of course on whether one is concerned about profits sacrificed or resources wasted.)

An organized futures market in HFCS, extending several years into the future, could have performed a valuable social role. The commodity itself was sufficiently standardized to present no serious obstacles to such an arrangement. Although producers might have been reluctant to enter into unconditional contracts to deliver a commodity they had never produced before, a more flexible standard contract could have been devised to shift a part of the production risk to the buyer. An active market in such futures contracts would have registered in price movements the developing information on the relationship of capacity and demand. Producers could have guided their capacity decisions accordingly. Soft-drink manufacturers and other potential HFCS buyers would have faced a clear measure of their incentive to convert from sugar to HFCS, and could have laid off to speculators most of the risk associated with their own investments in learning about the new sweetener. Of course, a functioning futures market is not a *tatônnement* on intertemporal prices; there is more to coordination than aggregating available information about actions taken. But there was no futures market, let alone a *tatônnement*. Perhaps there is a generalizable lesson here, a pessimistic principle that says that economic change rarely goes forward in an institutional context well suited for its guidance and control. Rather, the lag of institutional adaptations behind the need for them is a part of the problem of change.

It seems unlikely that the investment response of the corn wet milling industry to the HFCS opportunity came close to some plausible standard of ex ante optimality, but of course such questions are almost as difficult to judge in retrospect as in prospect. From the Porter and Spence account, it does seem clear that the investment choices of the industry as a whole did at least display a good deal of coherence. Viewed in a Schumpeterian perspective, their case study might even be appraised as a typical success story for the market mechanism, only slightly qualified by reference to the generalized (and perhaps unavoidable) failure to appreciate the depths to which the sugar price might sink. In the neo-Walrasian framework, however, the story hardly fits at all. The market mechanisms analyzed by Porter and Spence operate on different principles and perform different functions than the stylized market mechanisms of general equilibrium theory.

Starkly put, their explanation of how "coherence" was achieved and "chaos" avoided is that all firms computed the Cournot solution to the HFCS investment problem and acted accordingly. The Cournot model involved has a number of sophisticated elements, including demand uncertainty, mutual recognition of differentiating features of the oligopolistic rivals, and a range of qualitatively different investment options. But the basic coordinating force is the assumed general principle that the course of industry development anticipated by each individual firm is one it expects would be realized if it were generally anticipated. As the authors rightly remark, the acceptability of the Cournot equilibrium analysis in the context of the single-move investment game is considerably higher than it is in the more familiar context of output determination. It is important to emphasize, also, that they resort to equilibrium analysis not merely as a convenient theoretical device, but as a plausible abstraction of actual decision process in the industry—an answer to the question, *How is it done*?"

The most fundamental contrast between their analysis and neo-Walrasian equilibrium theory involves the informational role of prices. Prices are not sustaining equilibrium; they are signaling disequilibrium. The steps taken in response to disequilibrium are coordinated, imperfectly, by a variety of *nonprice* information flows and by actors' anticipating each other's behavior. The results of those steps are only tardily reflected in price movements, when it is too late to reconsider the steps but not to adapt to the new disequilibrium that they have produced. The players in the game need to know as much as possible about the details of each other's situation. In the Porter and Spence account *all* firms are performing the functions of the commissar for corn wet milling—a perspective sharply different not only from neo-Walrasian theory, but also from the Hayekian picture of the information processing economies of the market.

A number of features of the specific situation in the corn wet milling industry contribute to the plausibility of the explanation offered for the degree of coordination achieved.

—The situation involves a relatively short list of actors, all of whom are known to each other. A flood of *de novo* entry into the industry, from unidentified sources, is apparently not a sufficiently likely prospect to be taken into consideration. The firms involved evidently think, with reason, that they collectively "own" the new profit opportunity, although it is not immediately obvious what the ownership shares are.

—The actors can draw on a large fund of shared information about each other. The scale of past participation and previously revealed attitudes toward risks are particularly important indicators of likely future behavior. Prediction efforts based on this sort of information are not severely complicated by product differentiation or by secret development efforts proceeding simultaneously in several laboratories.

—Similarly, the actors share a fund of information about the demand side of the picture, derived from contacts with potential buyers and public sources. Again, the absence of product differentiation simplifies the problem of drawing inferences from this sort of information.

—Security analysts act as independent arbiters of expectations regarding the future prospects of the industry as a whole. Provided that the expectation thus certified is reasonably accurate and consistent with the reactions to it, this can make for improved coordination; otherwise, it can mean the investing firms are all wrong together.

—Firms communicate with each other through public statements, financial reports, and observable actions taken.

—Risk aversion and perhaps financial constraints limit recourse to preemptive strategies. These considerations operate to restrain and stabilize the aggregate industry investment to a degree that depends on the size of the contemplated investment opportunity relative to the size of the investing firms.

Any attempt to assess the generality of the mechanisms described, or to apply similar logic to other cases, might well focus on the extent to which these features of the original case are replicated.

I close these comments with a sketch of an alternative model of investment coordination in the situation studied by Porter and Spence, a model that seems to me to have somewhat greater behavioral plausibility than the Cournot-style computation they impute to the firms. In this alternative view, firms focus initially not on the capacity expansion path of the industry but on the full cost of production (including target return) of HFCS. This calculation would determine a price level just low enough to eliminate incentives for further additions to capacity. Consideration of the uncertain demand for HFCS would follow, resulting in a best estimate of the capacity likely to be ultimately installed, perhaps with a qualifying indication of high and low values. The first-cut answer to the question how the opportunity would be shared in the industry would be provided by reference to prevailing market shares in corn syrup. This preliminary estimate would then be modified by each individual firm according to its view of the special attributes and circumstances—including financial constraints, atypical cost conditions, and attitudes toward risk—of its rivals and itself. Such modifications would be constrained by the technical indivisibility of investment and would not be likely to go outside the range of plus or minus one MES plant. In finally carrying out its own plan, each firm would view itself as laying claim to its appropriate, historically based share of the new industry opportunity.

Like the Porter and Spence scheme, this alternative one has the central property that it would not, in many circumstances, produce "chaos" in the sense of a vast disproportion between the aggregate investment undertaken and the estimated size of the aggregate opportunity. Also like their scheme, there is a list of considerations that are highly relevant to its efficacy as a coordination device, but there is only a partial overlap between the two lists. In particular, the role played in their model by risk aversion is here played by the assumption that firms roughly scale their ambitions in the new market to their historical shares in the old one. This change amounts to a more explicit recognition of the fact that what the firms need to roughly coordinate their behavior is a Schelling (1960) focal point. Although the carrying out of the same Cournot equilibrium calculation by all parties might well provide the focal point if economic theorists were doing the calculating, I suspect that the historical shares approach would more readily come to the mind of the businessman.

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