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THE NUMERICAL ANALYSIS OF MONOPOLISTICALLY COMPETITIVE MARKETS: THE CASE OF A NEW YORK FRESH APPLE PACKER

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Abstract

The hypothesis is adduced that in some monopolistically competitive markets a firm's demand schedule evolves faster than the firm's marketing policies can adjust. A probabilistic model of this phenomenon is introduced. The numerical analysis of a New York fresh apple packer's inventory control policies illustrates the model's usefulness.

THE NUMERICAL ANALYSIS OF MONOPOLISTICALLY COMPETITIVE MARKETS: THE CASE OF A NEW YORK FRESH APPLE PACKER

Very few agricultural firms are monopolists, few are oligopolists, and many are not perfect competitors. Many can be considered monopolistic competitors in the Chamberlinian sense. Unfortunately, because product differentiation is too difficult to model analytically or because the Chamberlinian concept is misunderstood, few economic models capture the essence of Chamberlin's theory [Hart, p.889].

In this paper evidence is adduced which supports the hypothesis that in the short term, market conditions evolve more quickly than the firm's marketing policies can in some monopolistically competitive markets. A numerical model of a monopolistically competitive market is also presented, and the fresh apple market is used to illustrate the model's usefulness.

CHAMBERLINIAN MONOPOLISTIC COMPETITION REVISITED

The basis of Chamberlin's theory of monopolistic competition is product differentiation. For many agricultural products there exist close, but imperfect, substitutes. This assertion is supported by the existence of agricultural product grades and the growing importance of branding and direct consumer advertising of agricultural products (e.g. Kinnucan and Forker). As a result of product differentiation the firm faces a negatively sloped and, therefore, less than perfectly elastic demand curve.

A problem arises when one attempts to define Chamberlin's "product groups" . For example, is apple juice a substitute for orange juice?

Is chicken a substitute for beef? The consumer's perception of substitutability is the source of product differentiation. Advertising and other non-price competition are the sources of the perceived substitutability. The objective of non-price competition is to alter the shape of the firm's product demand curve by making competition "personal". Recall that "impersonal" relations between buyers and sellers is a necessary condition for perfect competition [Ferguson and Gould, p.314]. It is in the firm's interest to deny that its product has substitutes and, therefore, to create an effective monopoly.

In a perfectly competitive market, the firm sells all it can at the market price in the long-run. In the short-run, the firm is limited to its proportion of market demand [Chamberlin, pp.113-6]. In a monopolistically competitive market, the demand for a firm's product in a given time period depends in great part on the behavior of the other firms in the product group during the same period. Therefore, the monopolistically competitive firm makes its supply decision in an environment that is highly volatile and uncertain.

The derivation of profit maximizing output, q^*, for a monopolistic competitor is shown in Figure 1. The firm equates marginal cost and marginal revenue to determine maximum profit. One dimension of Figure 1 that is not explicitly stated is the time dimension. The demand curve, D, is only valid for a finite period of time. This is especially important in a monopolistically competitive market because D depends upon the actions of other members of the product group. So the time period for which D is valid depends upon the time it takes product group adjustments to affect firm demand. If the firm adjusts its marketing policies (e.g. attempt to equate marginal cost and marginal revenue) at

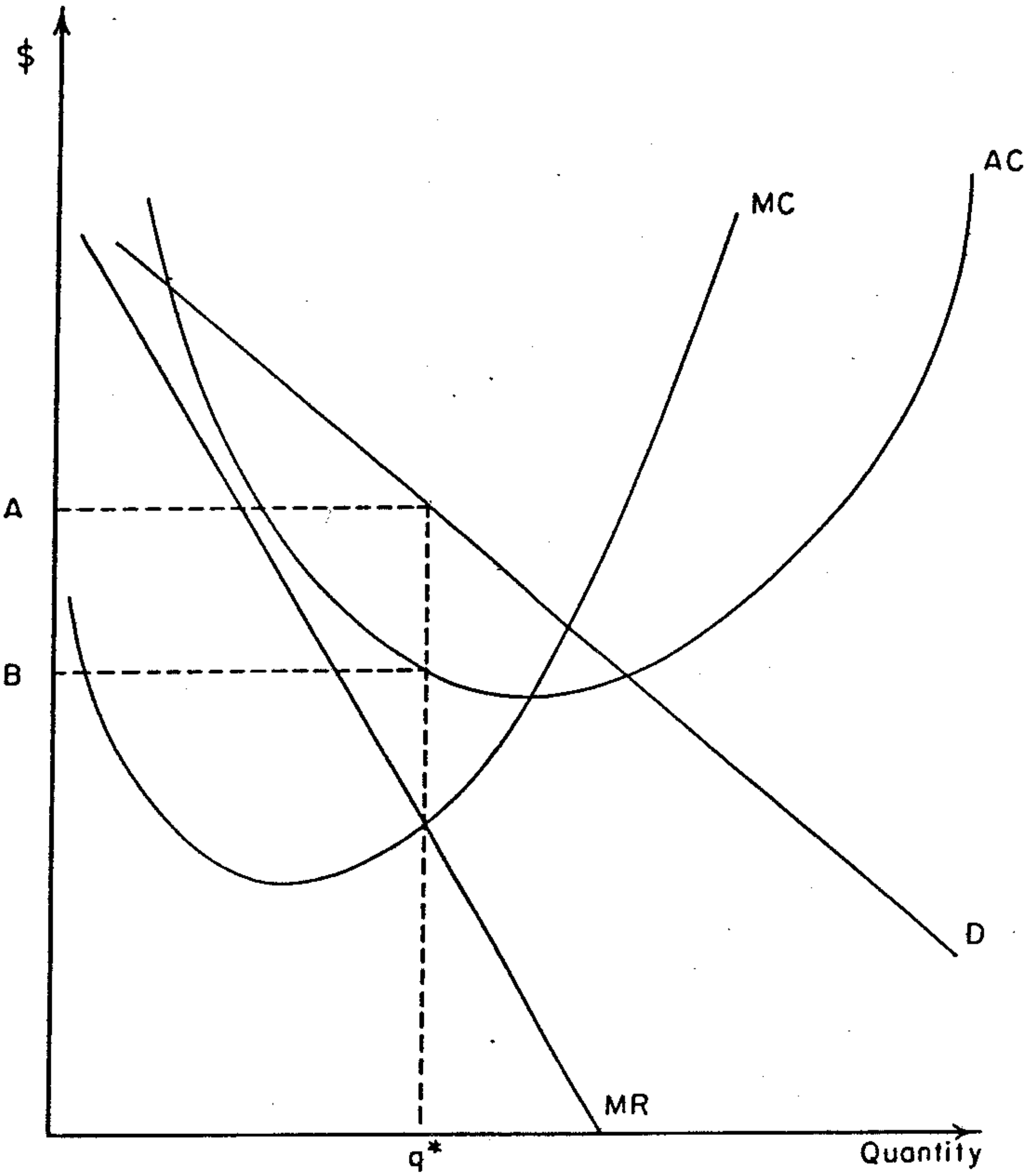

FIGURE 1. GRAPHICAL SOLUTION TO PROFIT MAXIMIZING OUTPUT IN A MONOPOLISTICALLY COMPETITIVE MARKET

time intervals longer than the interval between product group adjustments, then policies will apply to conditions that no longer exist when they are enacted.

Three characteristics of a monopolistically competitive market support the hypothesis that demand conditions may evolve faster than the firm can enact policy changes:

(1) The demand curve or schedule faced by a firm depends upon the actions of the other members of the firm's product group. Members of a product group are likely to make policy decisions at more or less the same time intervals. Unfortunately, between one firm's policy decisions several other firms may have made decisions. So by the time a firm enacts policy, the conditions which supported the policy no longer exist.

(2) The number of firms in the product group is so large that an individual firm cannot influence the demand it faces. If the number of firms was small then the firm might be able to predict the reaction of the competition and adjust policy with knowledge of future conditions. However, this is not the case and market conditions in the near future are unpredictable.

(3) The information the firm receives regarding the conditions of the market, especially with regard to the firm's demand curve, is imperfect and sporadic. Information is limited to points on the demand curve at unpredictable time intervals, i.e., quantity sold at the time of the sale. The demand schedule evolves faster than the firm's price can adjust because the demand schedule evolves faster than the firm receives information about the changes in the demand schedule.

The central hypothesis of this research asserts that because of the monopolistically competitive nature of some markets, the policy decisions made by firms (principally the pricing and supply decisions) evolve more slowly than market conditions (principally the demand curve facing the firm). Therefore, certain management decisions should not be based on market signals.

THE MODEL

If one accepts this hypothesis, then the price the firm charges has no influence upon the firm's demand schedule and the demand schedule does not significantly influence the price the firm charges. The price the firm charges depends upon market price, price of in firm substitutes for the product (e.g. the firm may produce several varieties of the same commodity), degree of perfection of information, and on-hand stocks (if the product is perishable). The demand schedule depends upon the behavior of other firms in the product group, upon the effectiveness of non-price competition, and upon the degree of perfection of consumer information.

These conditions imply that the frequency with which the firm charges a price is independent of the frequency with which the firm faces a particular demand schedule. So any price can occur with any demand schedule, and any demand schedule can occur with any price in a short period of time.

Consider the firm facing, in any given short period of time, $f(p,D)$, the joint density function for the random variables: price that the firm charges (p) and demand curve or schedule (D). If p is a continuous random variable and D is a discrete random variable then f(p,D)dp is the probability the price falls between p and p+dp and that the demand schedule is D.

One can also define marginal densities; functions which answer the question: what is the probability of p (or D) without regard to D (or p)?

$$\alpha(p) = \sum_{D=0}^{\infty} f(p,D) \qquad \beta(D) = \int_{-\infty}^{\infty} f(p,D)dp$$

The marginal densities allow us to define conditional probabilities as follows:

$$f(p,D)\ dp = h[(p|D)dp]\ \beta(D) = g(D|p)\ \alpha(p)dp$$

$$\text{if} \quad \beta(D) \neq 0 \text{ and } \alpha(p) \neq 0$$

where h[(p|D)dp] is the probability the firm charges between p and p+dp given D and g(D|p) is the probability the demand schedule D occurs given p.

Chamberlin argued that in a monopolistically competitive market there are enough firms such that the actions of one has no effect on the actions of others. This assertion can be used to adduce the following:

$$h(p|D)\ dp = \alpha(p)dp$$

i.e., that the probability of charging between p and p+dp given D equals the probability the firm charges between p and p+dp without regard to D. In other words the price the firm charges is not affected by the unknown demand schedule facing the firm in a short period of time.

The parallel assertion is as follows:

$$g(D|p) = \beta(D)$$

i.e. the probability demand schedule D occurs in a short period of time given it charges p is equal to the probability the demand schedule D occurs regardless of the price that the firm charges.

These claims imply independence, or that:

$$f(p,D) = \alpha(p) \quad \beta(D)$$

which is a joint distribution representing the frequency with which the firm charges p and demand schedule D occurs in the same short period of time.

AN ILLUSTRATION

The work done by Starbird et al. [1987] illustrates the use of the model described above. Starbird et al. modeled the prices and orders observed by a New York apple packing plant. The model described above was incorporated into a larger simulation model coded in SLAM II™, a computer simulation language. Data for daily prices and quantities ordered over the last three years were used to define the parameters of the computer simulation model. The simulation represented the storage and supply of seven different apple varieties under several control strategies.

Because of the number of imperfect substitutes and the importance of non-price competition in the fresh apple market, it can be described as monopolistically competitive. The characteristics which differentiate fresh apple products are variety and quality. In New York state over fifteen different fresh apple varieties are grown and marketed. In the eyes of many consumers these varieties are imperfect substitutes for one another. Quality also differentiates between fresh apple products. Quality is influenced by the age of the apples and by cultural practices.

The evidence suggests strongly that fresh apple marketing decisions are made more slowly than market conditions evolve because of the monopolistically competitive nature of the market. Consider Table 1 in which it is shown that the correlation between prices charged and quantity sold on a daily basis is not significantly different than zero for the top four varieties sold by the firm used in this example. This evidence does not prove that these variables are independent, but no correlation is a necessary condition for independence.

This example focuses on packing decisions at the end of the controlled atmosphere storage period (January to June). Many packers utilize CA storage in order to maintain supplies of apples into the winter and spring. The CA rooms are sealed when filled with apples in the Fall and cannot be resealed once they are opened. All the apples, usually several different varieties, removed from a CA room must be packed and sold before they deteriorate. So the decision to supply apples (open a CA room) is a critical one.

At the end of the storage period, the firm must determine when to supply apples, i.e., when to open the CA facilities. So the manager must adjust to rapidly adjusting market conditions by manipulating an acutely constrained supply. Empirical evidence suggests that the case firm used in this research rarely sells all its apples soon after a CA room is opened. Therefore, decisions made at the time the CA rooms are opened affect firm performance in future periods during which market conditions are not the same.

Nine alternative inventory control policies are analyzed. The first policy replicated the behavior of the firm in 1985, i.e., it represented the market oriented policy implemented by the firm in that year. This market policy was based upon the firm's interpretation of perceived prices and elasticities.

TABLE 1. CORRELATION COEFFICIENTS BETWEEN PRICE CHARGED BY THE CASE FIRM AND QUANTITY ORDERED ON A DAILY BASIS.

VARIETY	DEGREES OF FREEDOM	CORRELATION COEFFICIENT(r)	t STATISTIC
McIntosh	318	0.0398	0.7092
Red Romes	254	-0.0012	-0.0191
Red Delicious	249	0.0073	0.1150
Empires	139	-0.0262	-0.3079

The other eight policies were designed to reveal differences in performance due to (a) distribution of varieties to different rooms, (b) allocation of capacity within CA rooms, and (c) opening policies. The sensitivity of the results to changes in the frequency distributions representing quantity ordered was also considered.

The market environment of the firm was represented through fourteen frequency distributions. Seven frequency distributions represent the price of seven different apple varieties. Seven frequency distributions represent the quantity ordered per day of seven different apple varieties.

Developing a frequency distribution for a demand schedule is impossible because one cannot observe demand schedules. Starbird _et al._ used daily quantity ordered as a surrogate for the demand schedule. The discrete random variable D, demand schedule, represents a set of quantities and prices that correspond to one another in a given time period for a particular product of one firm. The upper limit of prices is defined by the prices of imperfect substitutes for the product and the lower limit on quantity is defined by the short term market's saturation point.

If q is the quantity ordered in a short period of time, the frequency with which q can occur depends upon the frequency with which the q appears in the set of feasible D's. Since the frequency with which demand schedules occur is stationary with respect to the price the firm charges, the frequency with which demand schedules intersect particular quantities is also stationary with respect to the price the firm charges. The probability that a quantity q is ordered without regard to price is equal to the probability a demand schedule D intersects q without regard to price.

Fortunately, one can observe the frequency with which q occurs and derive a marginal density function, B(q), for this variable. One can also observe the frequency with which a particular price is charged in order to derive a marginal density function, $\alpha(p)$, for this variable. Starbird et al. use the joint distribution, $f(p,q) = \alpha(p)B(q)$, to simulate the market conditions faced by the firm on a given day. It is assumed that the demand schedules and prices occurring in the next period are derived from the same frequency distributions which occurred in the last three years, i.e., that the marginal distributions representing these variables are stationary.

The effect of the alternative policies on firm performance is estimated from their effect on lost sales and lost premium. Sales are assumed to be lost if a control policy results in a shortage during a day, i.e., that the price charged by the firm and the firm's control policy results in a shortage. Orders are assumed to wait seven days before being lost. The value of the lost sales is assumed to be the revenue associated with an order. Premiums are lost if a control policy results in a surplus during a day, i.e., that the price charged by the firm, the demand schedule facing the firm, and the firm's supply control policy results in a surplus. The value of the premium is assumed to be tied to the deterioration of the apples. It was assumed that no significant deterioration occurred for seven days but that the value of the apples deteriorated 0.5% for each day after seven that the apples await orders.

The results indicates that in all cases a policy based upon inventory levels out performs the 1985 strategy based upon market' conditions. These results are insensitive to changes in the demand densities from stationary to non-stationary, and insensitive to changes in the premium calculation from linear to exponential. Lost premium was the source of improvement. Lost sales didn't significantly change.

An analysis of the variance in the results indicates that the opening policy, i.e., when to supply, is the most important of the three policy components. This result supports the hypothesis that inventory levels and not market conditions are a more relevant indicator of when to supply.

CONCLUSIONS

Several conclusions can be drawn from this study.

(1) In some monopolistically competitive markets, firms cannot enact policy changes as fast as market conditions change. This is particularly true in agricultural markets with many imperfect substitutes and highly constrained supplies.

(2) In representing markets with these characteristics, the modeler should reconsider the validity of economic models designed to represent longer run environments.

(3) The numerical analysis of a probabilistic model of market conditions is more appropriate for firms operating in a monopolistically competitive market exhibiting these characteristics.

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