An Analysis of Intraseasonal Apple Price Movements

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RESULTS OF AN ANALYSIS of U.S. apple prices at the farm level during the postwar period, 1947-61, are presented here.[1] The primary emphasis is placed upon determining and measuring the effects of factors associated with changes in apple prices during various periods of the apple marketing season. Previous work in this area has been quite limited. Most analyses of apple prices have dealt with changes in the season average price instead of focusing on intraseasonal or within-year price changes.

Season average farm price, as used in this study, refers to the average price during the marketing season. The apple marketing year is assumed to begin in July and end the following June. Many varieties and grades of apples are sold in the fresh market. The fresh price (reported monthly by the U.S. Department of Agriculture) is a blend price covering all varieties and grades.

Some of the more important policy questions in apple marketing cannot be answered on the basis of an analysis of season average prices. Among these questions are: (1) What is the most profitable allocation of apples between fresh and processing outlets? (2) Would a diversion program between alternative outlets be feasible for apple producers? (3) What part of the apple crop should be stored at harvest, and what is the optimum rate of movement from storage? In studying these problems, information is needed about demand conditions during various periods of the apple marketing season. This paper gives results of a model designed to provide this information.

The quantity of apples to store and the rate of sale from storage present major problems to the apple producer in each marketing season. Storage since World War II has been generally profitable only in certain years. Apple prices were lower at the time of storage during 4 of the 15 postwar years. In at least 2 of the remaining 11 years, the increase in price during the marketing season was not sufficient to cover storage costs.[2]

There is a problem in comparing apple prices at the beginning and end of the marketing season since the percentage of various grades and varieties marketed varies during the season. In general, however, the higher priced apples are placed in storage, so that the change in reported blend price may overstate the actual per bushel gross return to storage.

The decision as to whether to store apples must be made at harvest. At the same time supplies are being allocated to the fresh and processing markets, in areas where both outlets are available. These decisions are interrelated and the quantities stored and sold in each outlet are jointly determined with prices in the various markets. There are substitution possibilities on both the supply and demand sides.

On the supply side, approximately one-third of United States apples are "dual purpose" varieties.[3] These apples are about equally suitable for either fresh use or for processing. In addition, some varieties classified "fresh" are also often used in processing outlets. The problem in this case is to determine the most profitable allocation of the apple crop between fresh and processing forms of utilization. In addition to fresh vs. processing allocation, there is also a problem of distributing the fresh-market sales throughout the year at the most profitable rate.

On the demand side, empirical evidence suggests that consumers consider fresh apples and processed apple products to be

[1] Ronald A. Schrimper, Department of Agricultural Economics, North Carolina State, provided a number of helpful suggestions on an earlier draft of this paper.

[2] E. C. Pasour, "Analysis of Intraseasonal Apple Price Movements," Ph.D. dissertation, Michigan State University, Dept. Agr. Econ., 1963, p. 6.

[3] Dana G. Dalrymple, 'Economic Aspects of Apple Marketing in the U.S.," Ph.D. dissertation, Michigan State University, Dept. Agr. Econ., 1962, p. 16.

substitutes.[4] That is, a high price for processed apple products relative to fresh apples tends to increase fresh apple purchases. Substitution possibilities on the supply and demand sides result in a high degree of interdependence among apple markets at the farm level.

In this study, the Cromarty-Boger model was reformulated in view of structural changes in the U.S. apple industry since World War II.[5] U.S. apple exports and imports have been low in the postwar period. Consequently, I adjusted production data for exports and imports rather than formulate an export function (to explain changes in apple exports) as part of the overall model.[6]

The analysis was based on aggregation of the data into three within-year time periods or seasons. Selection of the specific periods used was based primarily on the economic and technical or physical characteristics of the apple industry, but was partly influenced by practical data limitations.

In the behavioral model of the apple market, quantities of apples stored, processed, and sold on the fresh market are jointly determined. As a result, the use of simultaneous equations to estimate the relationships comprising the economic model becomes logically appropriate during certain periods of the apple marketing season. For these periods, relationships were estimated using both ordinary least-squares and two-stage least-squares estimation procedures (5, pp. 258-260).[7]

After estimating the various relationships of the model, findings of this and other studies are related to apple marketing policy. Storage "rules" are developed to illustrate the possibility of improving storage decisions through the application of price prediction equations.

The Economic Model

The apple marketing year begins in July. Almost all apples are harvested during period I, July through November. During the harvest period, large quantities of apples are moved in the fresh market, but apple processing and storage are also important.[8] Thus, processing and fresh prices are determined simultaneously with the allocation by producers of apples into fresh or processing markets or into storage.

During period II, December through March, apples move out of storage to meet the demand in the fresh apple market. Apple processing occurring after period I is negligible and was ignored in this study.

Period III includes the months of April through June. When contrasted with period II, a much larger proportion of the apples sold in period III are controlled atmosphere (CA) apples.[9] In this study, all apples stored in any marketing season were assumed to be sold prior to July 1 since quantities sold after this date are very minor.

The total quantity of apples produced in any year was considered predetermined. Small quantities of apples may be left unharvested or culled during the marketing season because of price or price expectations. However, only to this very small extent can the season's supply of apples be considered endogenous.

Summary of the model.--Storage stocks information was obtained from the International Apple Association while quantities produced and processed were taken from publications of the Crop Reporting Board. A small quantity of apples

[4]W. H. Drew, "Demand and Spatial Equilibrium Models for Fresh Apples in the United States," Ph.D. dissertation, Vanderbilt University, Dept. Econ., Jan. 1961, pp. 213-214. At the retail level, Drew obtained a positive cross elasticity coefficient of 0.32 between fresh apple purchases and price of canned apples (the price elasticity of demand for fresh apples was -1.10). A positive cross elasticity coefficient of 0.67 was obtained between canned apple purchases and prices of fresh apples (the price elasticity of demand for processed apples was -0.73).

[5]W. A. Cromarty, "An Experiment in Designing an Econometric Model to Explain Short-Term Demand Fluctuations for Apples," M.S. thesis, Mich. State Univ., Dept. Agr. Econ., July 1953; and L. L. Boger and W. A. Cromarty, "A Model to Explain the Short-Term Demand for Apples," paper presented at Econometrics Society meeting, Washington, D.C., Dec. 28, 1953.

[6]The rationale for this decision is presented in Pasour, op. cit., pp. 23-33.

[7]Underlined numbers in parentheses refer to items in the Literature Cited, p. 30.

[8]From 1947 to 1961, processing utilization averaged about 30 percent of total apple production. The percentage of annual production of fall and winter varieties (which comprise about 95 percent of total production) in storage on December 1 varied between 35 and 45 during the same period.

[9]With this method of storage, a special atmosphere is maintained in a sealed storage room. The bulk of all stored apples is placed in regular refrigerated storage.

moves in and out of storage in period I, but the extent of this movement is not known.

All production and quantity variables were put on a per capita basis to adjust for changes in population. Since the periods of the analysis were of unequal length, quantity variables were put on a monthly or yearly basis to facilitate the comparison of coefficients for any given variable in different periods. To adjust for changes in the price level, farm prices were deflated by the Wholesale Price Index.

Income was assumed to be predetermined although changes in apple prices have a small influence on disposable income. Income data are reported on a quarterly basis and do not coincide with the three time periods used in this analysis. Income during period I was a weighted average of consumer disposable income during the third and fourth quarters. A weighted average of consumer disposable income during the fourth quarter of year t and the first quarter of year $(t + 1)$ was constructed to get y_{2t}. In period III, y_{3t} equals consumer disposable income in the second quarter.

In the formulation which follows, the jointly dependent or current endogenous variables appear first in each relationship and are separated from predetermined variables by a semicolon. The subscripts m and t indicate, respectively, the period and marketing year being considered. The period in which each relationship of the model holds is indicated by an X to the right of the relationship.

		Period	
	I	II	III
(1) $f_{mt}, p^f_{mt}; p^f_{(m-1)t}, y_{mt}, c_{mt}$	x	x	x
(2) $a_{1t} + f_{1t}, p_{\overline{1t}}; A_{1t}$	x		
(3) $p_{\overline{1t}} \equiv \gamma_1 p^f_{1t} + \gamma_2 p^a_{1t}$	x		
(4) $a_{1t}, \dfrac{p^a_{1t}}{p^f_{1t}}; m_t, n_t$	x		
(5a) $s_{1t}, \dfrac{p^a_{1t}}{p^f_{1t}}; m_t, n_t$	x		
(5b) $s_{2t}; k_{1t}, S_{1t}$		x	
(6) $S_{(m-1)t} + q_{mt} \equiv f_{mt} + a_{mt} + S_{mt}$	x	x	x

where:

f_{mt} = pounds per capita of fresh apples, moved out of storage (not necessarily sold) in period m and year t on a monthly basis (m = 1, 2, 3,; t = 1947, 1948, ..., 1961).

p^f_{mt} = farm price of fresh apples in cents per pound deflated by the Wholesale Price Index. Monthly prices (taken from "Agricultural Prices") were averaged to obtain the price indicator in each of the three periods.

p^a_{1t} = deflated season average farm price in cents per pound of all processing apples (from Crop Reporting Board statistics).

y_{mt} = per capita consumer disposable income in 100-dollar units, on an annual basis, deflated by the Consumer Price Index.

c_{mt} = per capita marketings (in pounds) of peaches, pears, and California table grapes. Sales rather than prices of competing fruits were included as an exogenous variable because sales are more nearly predetermined.

a_{1t} = farm sales of apples (in pounds) for processing on a per capita basis.

A_{1t} = per capita carryover stocks (in pounds) of canned and frozen apple slices and sauce in canners' hands at the end of July. These stocks would include almost entirely products carried over from the previous apple marketing season.

$p_{\overline{1t}}$ = a weighted average of p^f_{1t} and p^a_{1t}, where the weights, $\gamma_1 + \gamma_2$ (with $\gamma_1 + \gamma_2 = 1$), were based on sales of fresh and processing apples during period I.

m_t = per capita Eastern apple sales (in pounds) in year t. Eastern production is labeled as such by the crop reporting service. Production of 14 Eastern States from Maine to North Carolina is included.

n_t = per capita apple sales (in pounds) in other parts of the United States in year t. "Other production" equals total production less Eastern production.

S_{mt} = per capita apple storage holdings at the end of period m of year t.

$s_{mt} = S_{mt} - S_{(m-1)t}$. In period I, s_{1t} is positive. s_{mt} is negative in periods II and III indicating the rate of movement out of storage during the two periods.

k_{1t} = percentage of stored apples in CA storage on December 1.

Four stochastic functions [(1), (2), (4), and (5)] and two identities [(3) and (6)] comprise the model. Of the stochastic functions, (1) is a demand relationship for fresh apples,[10] (2) is a demand relationship for all apples sold in period I,[11] (4) is the allocation function for all processing apples, while (5a) and (5b) are storage functions for periods I and II, respectively. Of the identities, (3) defines $p_{\overline{1}t}$ and (6) is a storage-stocks relationship which holds during each period of the apple marketing season.

The latter identity states that for any period of any crop year, the supply of apples at the beginning of the period, $S_{(m-1)t}$, plus the quantity harvested during the period, q_{mt}, constitute the total supply. This supply is equal to the quantity stored at the end of the period, S_{mt}, plus the quantities sold during the period in the fresh market, f_{mt}, and in the processing market, a_{mt}.

The above formulation represents a complete economic model for apples during each of the three periods of the marketing season.[12] In the

model for period I, there is a demand relationship for fresh apples and one for total apple sales at farm level. In addition, apples may be stored during this period by the grower and moved into the fresh market later in the marketing season. Current endogenous variables in period I are f_{1t}, a_{1t}, s_{1t}, p_{1t}^f, p_{1t}^a, and $p_{\overline{1}t}$. Every relationship of the model holds in period I.

No processing occurs in period II. In this period, f_{2t}, p_{2t}^f, and s_{2t} are current endogenous variables. The fresh demand function (1), the storage function (5b), and the storage stocks identity (6) are the relevant relationships in period II.

In period III, storage movement is predetermined (movement equals stocks at beginning of period) and there is no processing. In this period, there is one current endogenous variable, p_{3t}^f, and the relevant relationships are (1) and (6). There is really just one equation since the identity in period III reduces to $S_{2t} = f_{3t}$ and f_{3t} is a predetermined variable in (1).

Each equation in periods I and II satisfies the necessary condition for overidentification in the standard linear simultaneous equations model; namely, the number of predetermined variables in the system less the number of predetermined variables in each equation is greater than the number of current endogenous variables in that equation minus one.

The Estimated Relationships

The estimated relationships were quite similar in log and nonlog form. In most cases, the results estimated in log form are not discussed.[13]

Relationships based upon 15 observations (1947-61) were estimated by ordinary least-squares (OLS) and by two-stage least-squares (TSLS).

In testing the regression coefficients, a one-tailed t test was used since a priori information indicates the direction of the effect of each predetermined variable upon the dependent variable. The 0.05 and 0.10 levels of significance

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[10] In this study, the quantity of apples sold was related to farm or wholesale prices along with a group of consumer "demand shifters" such as income and competing fruits. Hence, the demand relationships of this study are not behavior relations in the strict sense but are "partially reduced form" equations.

[11] In preliminary trials, the model contained a processing apple demand relationship. In this relationship, the quantity of apples processed was a function of processing price as well as carryover stocks and other possible demand shifters. Satisfactory results were not obtained in estimating this relationship (the coefficient of price was positive). Consequently, the model was revised to incorporate a demand function for all apples sold (fresh and processing) during the harvest period.

[12] The model is complete in the sense that there are as many equations as current endogenous variables in each period. In this study, functions were estimated to explain changes in quantities of apples which producers wish to store (s_{1t}) and to sell to processors (a_{1t}). The quantity producers sell fresh was treated as a residual. The choice of treating the quantity of fresh apples sold as a residual was largely arbitrary. With production predetermined, functions explaining changes in any two of the three quantities (f_{1t}, a_{1t}, s_{1t}) may be estimated and the third treated as a residual.

[13] Standard assumptions were made concerning the error term, u, in the estimation procedures of this study. See, e.g., Johnston (5, pp. 107, 232).

are considered relevant, and are designated by ** and *, respectively. Since two-stage error formulas are asymptotic, tests are only valid asymptotically, strictly speaking ([6], p. 5).

Period I.--The TSLS estimate of the model during this period follows.[14]

$$(1) \hat{f}_{1t} = 2.40 - 0.04p_{1t}^f - 0.08p_{3(t-1)}^f + 0.34c_{1t} - 0.06y_{1t}$$
$$t_b \qquad\qquad 0.39 \qquad 1.60 \qquad\qquad 2.25 \qquad 1.12$$
$$\bar{R}^2 = 0.63$$

$$(2) \hat{p}_{\bar{1}t} = 8.33 - 1.22(a_{1t} + f_{1t}) - 0.70A_{1t}$$
$$t_b \qquad\qquad 5.57** \qquad\qquad 4.29** \qquad \bar{R}^2 = 0.69$$

$$(3) \hat{a}_{1t} = -7.80 + 5.92\frac{p_{1t}^a}{p_{1t}^f} + 0.84m_t + 0.19n_t$$
$$t_b \qquad\qquad 2.77** \qquad 12.38** \quad 3.05** \qquad \bar{R}^2 = 0.92$$

$$(4) \hat{s}_{1t} = -2.61 - 0.13\frac{p_{1t}^f}{p_{1t}^a} + 0.24m_t + 0.68n_t$$
$$t_b \qquad\qquad 0.45 \qquad 1.93** \quad 6.53** \qquad \bar{R}^2 = 0.80$$

In accordance with traditional demand theory, the coefficient of price was expected to have a negative sign. Lagged fresh price was included as an explanatory variable on the presumption that consumption now and consumption next period are substitutes. Hence, an increase in $p_{(m-1)t}^f$ was expected to be associated with an increase in f_{mt}. Apples were assumed to be a normal good. An increase in carryover stocks, A_{1t}, was expected to decrease the demand by processors for apples in the current marketing season.

The results in period I seem quite good except for the demand relationship for fresh apples [(1)].

Coefficients of income (y_{1t}), competing fruits (c_{1t}), and lagged fresh price ($p_{3(t-1)}^f$) have "wrong" sings in (1). Downward trends in f_{1t} and c_{1t} and an upward trend in y_{1t} may provide an explanation of the perverse signs of c_{1t} and y_{1t}. The effect of fresh price on sales is not significantly different from zero at an acceptable level. When c_{1t} and y_{1t} were replaced by a trend variable and lagged price was eliminated, the estimated fresh apple demand relationship became more consistent with conventional demand theory.

The estimated demand function for fresh apples in period I when a trend variable was added and y_{1t}, c_{1t}, and $p_{3(t-1)}^f$ were dropped from the analysis with all data transformed to logs was:

$$(1-I) \quad f_{1t} = 8.57 - 0.35p_{1t}^f - 0.10T$$
$$t_b \qquad\qquad\qquad 1.70* \quad 2.97** \qquad \bar{R}^2 = 0.46$$

f_{1t} and p_{1t}^f are as defined previously in logs, and T = trend (1947 = 1, 1948 = 2, ..., 1961 = 15) in logs.

The elasticity of demand for fresh apples in period I based upon (1-I) was -0.35.[15] The elasticity of demand based on average prices and sales for all apples sold during the period computed from (2) was -0.60.[16] The effect of changes in period I total sales upon changes in average price was highly significant in this estimated relationship. A comparison of standard errors suggests, however, that the relationship between sales and price was measured more accurately in (2) than in (1-I). Also, the fit of (2) was considerably better than that of (1-I). The reason that demand functions were more satisfactory for combined fresh and processing apples than for fresh apples in period I is not clear. If demand is more inelastic for fresh apples than for total sales in period I, this implies that demand is more inelastic for fresh than for processing apples during the harvest period.

The trend variable in (1-I) was highly significant and indicates that the net effect of the many factors not included in the analysis was to decrease the demand for fresh apples.

Allocation function.--The allocation function for all processing apples explained a large part of the year-to-year variation in sales. All signs were as hypothesized. An increase in the

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[14] The $\bar{R}^2$ values presented along with relationships estimated by two-stage least-squares were based on estimated instead of observed values of all endogenous variables except the variable that is dependent in the second stage.

[15] When this relationship was fitted in nonlog form, the elasticity of demand at the mean values of price and quantity was -0.38.

[16] The reciprocal of price flexibility was taken to be the price elasticity of demand. In log form the elasticity of demand was -0.61.

processing-fresh-apple price ratio would tend to result in more apples being allocated to the processing sector. An increase in production would also tend to be associated with an increase in the quantity of apples processed. Since a much higher part of the Eastern States' crop goes into processing uses than the crops in other areas, it is not surprising that Eastern production (m_t) was a more important explanatory variable than other production (n_t).

Storage function.--A change in the ratio of fresh to processing apple prices had no significant effect on the quantity stored. The larger effect on initial storage of non-Eastern production seems reasonable since a larger proportion of these apples is moved in the fresh market.

The fresh apple demand function was the least satisfactory of the estimated relationships for period I. In general, OLS and TSLS estimates were quite similar. In retrospect, it is not surprising that the estimating procedures yielded similar results of (2) and (5a), for the following reason. In period I, production is predetermined and initial storage was shown to be mainly determined by production. Since $q_{1t} = a_{1t} + f_{1t} + s_{1t}$, then $a_{1t} + f_{1t}$ should be largely predetermined. Thus, one might expect the OLS estimate of (2) to be quite good when this relationship is estimated with the price dependent.

Period II. In period II, the producer has the alternative of selling on the fresh market or of leaving his apples in storage for sale in period III. Hence, the quantity of apples remaining in storage and fresh sales from storage, f_{2t}, are jointly determined. In the storage function of period II, s_{2t} is negative. The estimated relationships of period II (TSLS) are:

$$(1\text{-}II) \quad \hat{p}_{2t}^f = 9.66 - 2.37f_{2t} + 0.41p_{1t}^f - 1.15c_{2t} - 0.13y_{2t}$$
$$t_b \qquad\qquad 8.29** \quad 2.83** \quad 2.53** \quad 2.12$$
$$\bar{R}^2 = 0.92$$

$$(5b) \quad \hat{s}_{2t} = 1.90 - 0.58S_{1t} + 0.04k_{1t}$$
$$t_b \qquad\qquad 14.67** \quad 1.70*$$
$$\bar{R}^2 = 0.95$$

These results are generally consistent with a priori reasoning. [17] In (1-II), however, the

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[17]OLS and TSLS estimates differed little in period II. This is not surprising since s_{2t} (hence, f_{2t}) from (5b) is shown to be largely determined by s_{1t} and k_{1t} which are predetermined.

coefficient of income has the "wrong" sign. It is likely that the effect of income which has a strong upward trend is being masked by the effects of other variables.

At the mean values of sales and price, demand was inelastic for fresh apples in period II (-0.78) but appeared to be more elastic in period II than in period I.

Initial storage stocks, S_{1t}, from 1947 to 1961, explained about 93 percent of year-to-year changes in storage stocks during period II. These stocks constitute the total available supply during period II since harvest is completed during period I. Apples, in general, will be stored and remain in storage as long as the expected price at a later date exceeds the current price plus storage costs (allowing for risk, spoilage, etc.). An increase in S_{1t} is likely to adversely affect the producers' expectations concerning future prices. With constant storage costs, a decrease in expected future price would likely be associated with an increase in movement from storage during any period.

CA storage costs are approximately one and one-half times as high as costs of regular refrigerated storage. This increase in costs, however, has been more than compensated for by the price premium realized for CA apples. Under these conditions, one might expect an increase in CA storage to be associated with an increase in future price and a decrease in movement from storage in period II.

The estimated storage functions for periods I and II indicate that the aggregate behavior of apple storage operators can be represented quite accurately by simple functional relationships of the type used in this study.

Period III. All apples in storage at the beginning of period III are sold (in the fresh market) during the period. In this case, the OLS method of estimation (with price dependent) becomes a valid application of the simultaneous equations theory and the methods are identical. The estimated relationship of period III was:

$$(1\text{-}III) \quad p_{3t}^f = 3.03 - 2.63f_{3t} + 0.49p_{2t}^f + 1.21c_{3t} + 0.09y_{3t}$$
$$t_b \qquad\qquad 3.89** \quad 2.79** \quad 1.41 \quad 0.81$$
$$\bar{R}^2 = 0.84$$

Only the coefficient of competing fruits (c_{3t}) has the "wrong" sign in (1-III). It is likely that

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c_{3t} is acting as a proxy variable for factors not included in the analysis.

In periods II and III, an increase in fresh price in the previous period was associated with a price increase in the current period. These results alone do not support the hypothesis that consumption is substitutable between periods since prices in successive periods are highly positively correlated. However, similar results were obtained when quantity was considered dependent. Thus, consumption appears to be substitutable between periods, at least to some extent.

The elasticity of demand in period III, at the mean values of fresh sales and price, is -1.85 -- apparently higher than the elasticities of periods I and II.[18] However, the average quantity of sales was less in period III than in period II and was less in period II than in period I.

Elasticities computed from annual data by other researchers were similar to those computed in this study. Using simultaneous equations estimation procedures with annual data, Tomek and Brandow obtained elasticities of -0.46 and -0.73, respectively, for fresh apples. Elasticities obtained for processing apples were -0.57 and -0.21 ([1], p. 20; [10], pp. 26-28).

Seasonal Changes in Elasticity of Demand

Elasticity of demand for most commodities is likely to vary depending on the length of time involved. There are two opposing forces affecting the elasticity of demand. Short-time elasticities (e.g., week or month) are likely to be greater than longer-time elasticities (e.g., year) since a large part of the short-term fluctuations in quantities marketed can be absorbed by storage operations ([8], p. 64). Annual fluctuations in quantities marketed of a semiperishable commodity such as fresh apples, however, cannot be absorbed in this manner.

The ease of substitution is another force affecting elasticity of demand. The more time allowed for adjustment to a price change, the greater the adjustment is likely to be. Thus, we expect elasticities to be greater in the long run than on an annual basis. Within short periods of time, the substitution effect on elasticity is likely to be more than offset by the opposite effect of storage.[19]

In addition to problems with respect to the time period involved, the demand function may shift during the season. A limited amount of empirical work has been concerned with intraseasonal shifting of demand for fruits and vegetables. In demonstrating that intraseasonal shifts in demand occur, it must be shown that intraseasonal price changes cannot be explained by changes in quantity placed on the market. Results of this study suggest that the demand for fresh apples is more inelastic than the demand for processing apples during the harvest period. Demand for fresh apples appears to become less inelastic as the marketing season advances and to become elastic near the end of the marketing season.

Implications

There is current interest in exploring alternative apple marketing policies. A diversion program for fresh and processing apples has been discussed by a number of writers ([2] and [3]). Under a program of one type, sales of fresh apples would be restricted and the surplus allocated to processing outlets. The underlying premise of such a program is that the demand for fresh apples is more inelastic (at the farm level) than the demand for apples going to processors. Empirical evidence concerning the relative elasticities of demand for fresh and processing apples at the farm level is mixed. An additional difficulty is that these estimates were based on annual data and results from this study indicate that the elasticity of demand for fresh apples may vary during the marketing season.

A satisfactory demand function for processing apples was not obtained in this study.[20] The

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[18] When all data were transformed to logs, the elasticity of demand was -1.33 in period III.

[19] The first force might also be considered as representing a substitution effect of a special kind. That is, the short-term fluctuations in quantities marketed absorbed by storage operations represent a substitution of consumption in a later time period for consumption in the present time period. The shorter the period of time involved, the easier it is to make this substitution.

[20] Price prediction functions for processing apples were more satisfactory ([7]). See E. C. Pasour and D. L. Oldenstadt, "Farm Prices of Apples for Canning and Freezing in the United States, 1951-1961," U.S. Dept. Agr., Agr. Econ. Rpt. No. 35, (Washington: U.S. Government Printing Office, 1963.)

evidence indicated that fresh apples in period I had a more inelastic demand than the demand for total sales, implying that the demand was more elastic for processing apples. The analysis was not adequate, however, to conclude that there was, in fact, a difference in the elasticity of demand in processing and fresh apple markets. In view of the uncertainty and conflicting empirical findings with respect to the relative elasticities of fresh and processing apples at the farm level, a diversion program for apples does not appear feasible to this writer at the present time.

Optimum allocation over time.--Another policy problem revolves around the question of how to optimally allocate fresh apples during the marketing season. Theoretically, returns can be maximized by allocating a commodity over time in the same way as between different markets at any given point in time. Net returns would be maximized when the marginal revenues were equal in each time period, assuming marginal costs were equal.

When a difference in time is involved, there is usually a difference in total costs due to storage costs, and possibly in marginal costs. The allocation principle remains the same, however, when marginal costs differ in different time periods. In such cases, net returns would be maximized by equating marginal net revenue in each time period, where marginal net revenue is defined as the difference between marginal revenue and marginal cost in any market.

In the case of apples, net returns would be maximized over time by equating properly discounted marginal net revenues in fresh and processing markets for periods I, II, and III. Information relating to storage costs and demand conditions in various periods of the apple marketing season is necessary to determine the most profitable marketing pattern. The attempt to determine separate demand functions for fresh and processing apples during the harvest period in this study was not successful enough, it was felt, to warrant using the estimated functions as the basis for constructing marginal revenue functions. Estimated price prediction equations, on the other hand, appeared relatively satisfactory. In the following section, to illustrate the possibility of improving storage decisions by use of price prediction equation, storage "rules" are developed such that (a) the

quantity in storage at the end of period m (for m = 1, 2) is a specified function of variables observable in or before period m, and (b) the parameters of the function are determined so as to equalize the marginal cost of storage and the expected change in price. Equating marginal cost of storage and expected change in price does not maximize producers' or storers' expected revenue, but it does maximize the expected "social value" of storing activity, provided one accepts market price as the measure of the "marginal social value" of the commodity in utilization (4).

Storage Rules

The average within-year price increase from period I to period III during the period 1947-61 was $0.26 per bushel. Storage costs are about $0.23 per bushel for regular storage and $0.37 per bushel for CA storage and most apples are stored in regular storage facilities (9, p. 56). Hence, on the average, the price increase during the period of storage appears to have approximated the cost of storage. However, there has been wide variation from year to year in within-year price movements, and ipso facto large deviations in particular years from equality of price change with cost of storage.

Storage costs used in the following analysis were based on Thompson's study of apple storage costs in New York State (9). Storage costs, however, appear to be fairly constant over the United States. Marginal storage costs were assumed constant in developing the storage rules. After apples are stored, fixed costs of storage do not offset storage decisions in subsequent periods and variable storage costs are quite low. Storage costs between periods I and II and between periods II and III were taken to be $0.22 and $0.04 per bushel, respectively.[21]

Predictive equations for fresh apple prices.-- In developing storage rules, price prediction equations are needed for each of the three periods of the analysis. Fresh apple price is difficult to predict early in the marketing season.

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[21]The cost of storage in each period was weighted by the average percentage of apples in regular and CA storage facilities in that period.

A fairly good predictive relationship for fresh price in period II was obtained using July fresh price and the July apple crop estimate of the Department of Agriculture as explanatory variables. The July apple crop estimate during the postwar period has been quite accurate as an indicator of total production.

This estimated relationship based on data for the period 1947-61 is:

$$(7)\ \hat{p}^f_{1t} = 2.33 + 0.39 p^f_{jt} - 1.76 e_{jt}$$
$$t_b \qquad 1.73^* \qquad 3.49^{**} \qquad\qquad \bar{R}^2 = 0.67$$

where

p^f_{1t} = deflated U.S. average farm price in dollars per bushel of fresh apples in period I of year t.

p^f_{jt} = deflated U.S. average July farm price of fresh apples in dollars per bushel in year t.

e_{jt} = U.S. Department of Agriculture July apple crop estimate (for the United States) in bushels per capita in year t.

Lagged fresh price, $p^f_{3(t-1)}$, was initially included as an explanatory variable in this relationship. The effect of lagged fresh price, however, was not significant at the 0.10 level and it was dropped from the equation.

Changes in period I fresh price were closely associated with changes in total production or forecast. Taken together, July fresh price and apple crop estimate explained almost 70 percent of the variation in period I fresh prices from 1947 to 1961.

Relationship (7) was used instead of the fresh apple demand relationship of period I estimated in the previous section in developing storage rules for the following reason. As a fresh price predictive relationship, (7) explains a higher percentage of the period I price variation and contains explanatory variables estimated by the U.S. Department of Agriculture early in the apple marketing season.

Estimated relationships to predict fresh apple prices in periods II and III were adapted from the relationships previously presented. This involved elimination of lagged price as a variable from (1-II) and (1-III), and reestimation of these relationships by replacing c_{mt} and y_{mt} with

a trend variable. When lagged price was left in, the quantity to store in the storage rule for period I or II was a function of current price.

The estimated relationships obtained for periods II and III are:

$$(8)\ \hat{p}^f_{2t} = 5.21 - 1.47 f_{2t} - 0.02 T_1 \qquad\qquad \bar{R}^2 = 0.84$$

$$(9)\ \hat{p}^f_{3t} = 3.63 - 2.44 f_{3t} + 0.01 T_1 \qquad\qquad \bar{R}^2 = 0.73$$

where:

p^f_{mt} = deflated U.S. average farm price in dollars per bushel of fresh apples in period m of year t.

f_{mt} = per capita sales (in pounds) of fresh apples in period m and year t on a monthly basis.

T_1 = trend (1947 = 1, 1948 = 2, ..., 1961 = 15).

Storage rule for period II.--In determining how many apples should be in storage at the end of period II, S_{2t}, the expected price change between periods II and III, is equated with marginal cost of storage between these periods. That is, the equation to be satisfied is:

$$(10)\ 5.21 - 1.47 f_{2t} - 0.02 T_1 = 3.63 - 2.44 f_{3t} + 0.01 T_1 - 0.04$$

where the left side is price in period II, the first three terms on the right are expected price in period III, and the fourth term on the right is the (constant) marginal cost of storage between periods II and III.

The quantity of sales during period II, f_{2t}, is equivalent to the quantity in storage in the beginning of period II, S_{1t}, less the quantity in storage at the end of the period, S_{2t}. All apples in storage at the end of period II are moved during period III. Consequently, $f_{3t} = S_{2t}$.

Substituting $(S_{1t} - S_{2t})$ for f_{2t} and S_{2t} for f_{3t} in (10) and solving for S_{2t}, we obtain S_{2t} as a function of S_{1t} and T_1. When these substitutions are made, the storage rule of period II is:

$$(11)\ \hat{S}_{2t} = 0.41 + 0.38 S_{1t} + 0.01 T_1$$

where:

S_{mt} = the quantity of apples stored at the end of period m in year t in pounds per capita.

Thus, the quantity of apples in storage at the end of period II under rule (11) is a positive function of the quantity on hand at the beginning of period II and the trend variable.

The storage rule for period II when net marginal revenues are equated in period II and III (instead of equating the expected price change) follows.

From (8) and (9) and the cost assumption, it follows that:

$$TR_{III} = p^f_{3t}f_{3t} = 3.63f_{3t} - 2.44f^2_{3t} + 0.01T_1f_{3t}$$

$$TR_{II} = p^f_{2t}f_{2t} = 5.21f_{2t} - 1.47f^2_{2t} - 0.02T_1f_{2t}$$

$$TC = .04S_{2t}$$

Then,

$$MR_{III} = 3.63 - 4.88f_{3t} + 0.01T_1$$

$$MR_{II} = 5.21 - 2.94f_{2t} - 0.02T_1$$

$$MC = 0.04$$

Substituting $S_{1t} - S_{2t}$ for f_{2t} and S_{2t} for f_{3t}, setting $MR_{II} = MR_{III} - MC$, and solving for S_{2t}, we obtain the storage rule,

$$S_{2t} = -0.21 + 0.38S_{1t} + 0.004T_1$$

which maximizes net returns in periods II and III. This rule is similar to (11). The coefficient of S_{1t} (the slope) is the same in each case, while the level of S_{2t} for a given quantity of S_{1t} is lower in the case where net returns are maximized.

Both of the "derived" storage rules for period II are similar to the estimated storage equation for that period which was

$$\hat{s}_{2t} = -1.90 - 0.58S_{1t} + 0.04k_{1t}$$

or since $S_{2t} = S_{1t} + s_{2t}$

$$\hat{S}_{2t} = -1.90 + 0.42S_{1t} + 0.04k_{1t}$$

Storage rule for period I.--In period I, the equation to be satisfied is:

$$(12)\ 2.33 + 0.39p^f_{jt} - 1.76e_{jt} = 5.21 - 1.47f_{2t} - 0.02T_1 - 0.22$$

where the left side is price in period I, the first three terms on the right are expected price in period II, and the last term on the right is the (constant) marginal cost of storage between periods I and II. Substituting $(S_{1t} - S_{2t})$ for f_{2t} and equation (11) for S_{2t} gives the following storage rule for period I:

$$(13)\ \hat{S}_{1t} = 2.26 - 0.43p^f_{jt} + 1.93e_{jt} - 0.01T_1$$

In this case, the quantity stored in period I is a function of July fresh price, July crop estimate, and the trend variable.

Application of Storage Rules

After the storage rules [(11) and (13)] were computed, they were applied to the years 1947-61 to see what difference their application would have made in the variability of seasonal price changes. For each year, using equation (13), the quantity was computed that would have been stored in period I applying the storage rule, $\hat{S}_{1t}$. Then substituting the quantities that would have been stored under the storage rule of period I, $\hat{S}_{1t}$, into (11), $\hat{S}_{2t}$ was computed for each year of the analysis.

After computing $\hat{S}_{1t}$ and $\hat{S}_{2t}$ from the storage rules, sales for periods II and III under the storage rules were computed. In these computations, $\hat{f}_{2t} = \hat{S}_{1t} - \hat{S}_{2t}$ and $\hat{f}_{3t} = \hat{S}_{2t}$. Then, the demand functions estimated in this study were used to determine the price that would have occurred in periods I, II, and III had the storage rule been in effect. The observed price of each period was adjusted by the following procedure which assumes that other factors affecting demand, e.g., competing fruits, income, etc., would not have been affected by the storage rules.

$$(14)\ \hat{P}_{mt} = p^o_{mt} - b_m(\hat{f}_{mt} - f^o_{mt})$$

where:

$\hat{P}_{mt}$ = the price which would have occurred in period m of year t had the storage rule been in effect.

p^o_{mt} = the observed price in period m of year t.

b_m = the regression coefficient of sales in the fresh apple demand function of period m.

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$\hat{f}_{mt}$ = quantity of sales in period m of year t under the storage rule.

f^o_{mt} = the actual quantity of sales in period m of year t.

In period I, the difference in total apple sales due to the storage rule during the period 1947–1961 would be $(\hat{S}_{1t} - S^o_{1t})$, where S^o_{1t} is the quantity actually stored in period I and $\hat{S}_{1t}$ is the quantity that would have been stored under the rule (13). In computing $\hat{P}_{1t}$, b_1 was the regression coefficient of sales in the estimated demand relationship (of period I) for both fresh and processing apples presented previously.[22]

The change in fresh sales in period II that would have occurred had the storage rules been applied was determined as follows. Since $f_{2t} = S_{1t} - S_{2t}$, we have:

$$(15) \quad \hat{f}_{2t} - f^o_{2t} = \hat{S}_{1t} - S^o_{1t} + S^o_{2t} - \hat{S}_{2t}$$

where all quantities are as previously defined. In period III, $f_{3t} = S_{2t}$. Therefore, $\hat{f}_{3t} - f^o_{3t} = \hat{S}_{2t} - S^o_{2t}$.

After computing the prices which would have occurred in period m and year t under the storage rules, $\hat{P}_{mt}$, seasonal price changes in $\hat{P}_{mt}$ were compared with seasonal price changes in observed price, p^o_{mt}. This comparison follows. Let

$$D^o_{12} = P^o_{2t} - P^o_{1t}, \quad D^o_{23} = P^o_{3t} - P^o_{2t}, \quad D^o_{13} = P^o_{3t} - P^o_{1t}$$

$$\hat{D}_{12} = \hat{P}_{2t} - \hat{P}_{1t}, \quad \hat{D}_{23} = \hat{P}_{3t} - \hat{P}_{2t}, \quad \hat{D}_{13} = \hat{P}_{3t} - \hat{P}_{1t}$$

D^o_{ij} is the observed price change between period i and j, and $\hat{D}_{ij}$ is the price change between period i and j which would have occurred under the application of the derived storage rules, (11) and (13). The variances of D^o_{ij} and $\hat{D}_{ij}$ were computed for the period

1947–1961. These results are summarized below.

	Periods of the Analysis		
	I - II	II - III	I - III
Variance of actual price changes (D^o_{ij})	0.095	0.089	0.212
Variance of estimated price changes $(\hat{D}_{ij})$	0.089	0.064	0.053
Ratio of variances $\left(\dfrac{\text{estimated}}{\text{observed}}\right)$	0.937	0.719	0.250
Percentage decrease in variance under the derived storage rule	6%	28%	75%

There was a large reduction in variance (under the storage rules) of the price change from period I to period III, but the other two reductions were quite modest. The explanation for this outcome is not clear, but the computations at least suggest the possibility of improving storage decisions through the use of price prediction equations.

The decrease in variability in the seasonal price change under the storage rules would, in this case, have been accompanied by an increase in total revenue. In a comparison of sales and prices computed from the storage rules with actual prices and sales, total revenue was higher under the rules in 13 of the 15 years included in the analysis. The average annual increase in total revenue under the rules was about 2 percent. The application of the rules would have affected total costs very little since the average quantity stored under the rule was about the same as the actual average quantity stored. Hence, the percentage increase in net revenue would have been greater than the percentage increase in total revenue.

The above computations are indicative of the possible magnitude of the effect of improved storage decisions. The rules, however, were only applied to the same data from which the rules were developed, so that the substantial reduction in variability of the price change from period I to period III which was obtained is undoubtedly an "upper limit" estimate of the improvements which might be possible using price prediction equations of the fairly simple type presented

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[22] A weighted price (weighted by f_{1t} and a_{1t}) was used as the price indicator in the demand relationship for combined fresh and processing sales. When this function was re-estimated with p^f_{1t} as the dependent variable, the coefficient of $(a_{1t}+f_{1t})$ changed very little (from -1.17 to -1.15).

here.[23] That is, if the rules were applied to data for a different period of time, the reduction in variability of the price change from period I to period III would probably not be as large as that obtained in this study.

The computed storage rules are aggregate inventory functions. Such rules, however, could be of value to individual apple producers. Apple harvest occurs only in period I. Prices during the remainder of the season are greatly influenced by the quantity of apples initially stored and the rate of sale from storage. Apple storage is profitable if the increase in price is more than enough to cover the costs of storage. Hence, if it appears that aggregate apple holdings will be less than that called for by (13) for period I or (11) for period II, the individual producer might profitably increase the quantity stored in period I or defer sales from period II to period III.

During the postwar period, changes in initial storage holdings in period I were explained quite well by the simple storage function presented earlier. After harvest, more than 90 percent of the change in storage movement between periods II and III was explained by change in initial storage holdings. The International Apple Association publishes monthly storage reports which indicate the level of aggregate storage holdings. The individual firm might use such data in conjunction with the storage rules to determine whether or not to change its own storage holdings. Such information could provide a basis for more orderly marketing.

The substantial degree of aggregation, geographic, temporal, and among grades and varieties may conceal profit opportunities associated with storage. Price variation within periods, differential rates of flow of apples within periods, and differing patterns of seasonal price variation in different regions may be misleading to producers in particular regions.

A further complicating factor in developing a storage policy for the apple industry is that all producers do not have the same costs and the same expected returns. For example, both costs and returns are higher under CA storage conditions. The individual producer needs information pertaining to his specific apples. However, a knowledge of total storage holdings and the probable price increase for all apples is useful since there is generally a high degree of substitution among varieties and grades of apples produced in different locations.

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[23] Gustafson found, however, that a substantial reduction in the year-to-year variability of seasonal changes in price could be achieved by the application of storage rules, when the rules were based on data from an entirely separate period of years. (R.L. Gustafson, "Storage of Pork," unpublished manuscript, Mich. State Univ., 1959.)

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