The U.S. Apple Industry: Econometric Model and Projections

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A dynamic model of the U.S. apple industry, including relationships for bearing acres, production, utilization, and allocation to the fresh, canned, frozen, juice, dried and other markets, is specified. Demands for each of these markets are modeled. Model coefficients are obtained using Zellner's seemingly unrelated regression procedure and data from 1971 through 1990. Elasticities and flexibilities are compared with other studies. Projections indicate that price fluctuations will continue in the industry when acreage is held at 1990 levels. A ten percent increase in fresh exports strengthens all apple prices. However, a ten percent decrease in the price of juice imports mitigates some of this effect.

Apples are grown in thirty-five of the fifty states in the nation. Nearly five hundred thousand acres are in commercial production yielding nearly ten billion pounds of fruit each year. This production is equivalent to over a billion dollars in revenue for the nation's apple growers (USDA 2). Ten states account for nearly 90 percent of the U.S. apple crop, while Washington, New York and Michigan produce nearly 70 percent of the crop (Sparks et. el.) Once produced, these apples are allocated to alternative product markets. Historically, the fresh market has claimed over fifty percent of the apple harvest. The processed market consists of those apples used for canning and freezing, juice, dried apples, and other products.

The domestic apple industry has been faced with several economic issues over the past few years. Some of these include increased concern about chemicals used in the production process affecting the demand for the fruit. Some of the new fruit varieties are disease resistant and require less chemical application, yet they do not have clear marketing channels (Murphy and Willett). The industry is faced with increasing juice imports and decreasing prices of these imports. Since 1980, per capita juice imports have increased over twenty-five percent per year, while per capita consumption of apple juice increased by less than six percent per year (USDA 2). The real price of juice imports declined from $1.28 in 1979 to $0.56 per gallon in 1990, an average of four percent per year (USDA 1).

The objectives of the research reported here were to (1) identify the factors affecting the supply and demand for U.S. apples, (2) determine the degree of substitutability and complementarity of apple products, and (3) estimate changes in domestic apple consumption, production, and prices under various industry scenarios.

To achieve these objectives annual data relating to acres, production, prices, utilization, imports, and exports were collected from secondary sources. A model of the industry was conceptualized and assumptions were made concerning the characteristics of the individual equations, the relationships between the equations within a sector, and the association between model sectors. Model coefficients, their t ratios, and equation statistics were evaluated. Finally, dynamic deterministic simulation techniques were used to assess the impacts of changes in acreage, fresh exports and juice import price on production, consumption and prices in the industry.

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ECONOMIC MODEL

Studies dealing with the apple industry date from an analysis of the production outlook of apples in

Michigan in the mid-1950s's (French) to the analysis of the demand for fresh apples in four import markets in the 1990's (Sparks et. al.). Tomek developed a supply-demand model of the industry using data from 1947 through 1966. The model included supply and demand equations for fresh apples, frozen and canned apples, and other apple products. He used the model to forecast 1975 production, demand, and prices. Hayward et. al. developed a model of the apple industry in Maine and the United States using data from 1960 through 1981. Their econometric model incorporates the rate of size-controlled tree adoption. Using data from 1952 through 1981, Baumes and Conway estimated an econometric model including demand, domestic market allocation, and margin equations for the fresh and processed apple markets. Rae and Carman developed a detailed perennial crop supply model of the New Zealand apple industry using data from 1958 through 1972. In 1976, Piggott published an article comparing a perfectly competitive, monopolistic and quasi-monopolistic apple industry. Recently, Chaudry developed and estimated an econometric model of the industry that incorporates demand and allocation decision-making in various regions of the U.S. and during different time periods within the market year. He used data from 1959 through 1984 for his analysis. There have been other models of the apple industry that focus on interregional competition. Miller, Dunn and Garafola, and Fuchs et al. are some examples.

Development of this structural model of the apple industry draws on the experience and results of these researchers. This model of the apple industry is composed of three sectors: 1) supply, 2) allocation, and 3) demand. The supply sector includes relationships describing the change in bearing acres, and yield per acre. Allocation of production is made to the fresh and processed markets and subsequently to the canning, freezing, dried, juice, and other product markets. Demand functions for each of these products are specified in the demand sector. Net imports of apple products, with the exception of juice imports, are assumed to be exogenous. Functions relating the price of each product to the processed price and the average apple price are specified.

Hence, the model of the industry presented here contributes to the research on the apple industry by providing a more detailed analysis of the allocation to various marketing outlets and the demand for these products. Furthermore, the model incorporates production of apples and the demand for juice imports in detail.

Data used for model estimation covers a more recent period, 1971 through 1990, than previous studies. Data are annual values and reflect the crop year (August to July). All monetary values in the model are deflated by the gross national product deflator. All quantity variables in the demand sector are expressed in per capita terms. Model equations and variable definitions can be found in Tables 1 and 2, respectively.

Supply Sector

Apples, a perennial crop, are produced by profit maximizing producers who are assumed to maximize the net revenue they receive from their outputs subject to the technical constraints imposed by their production function. Following the development of the perennial crop model by French and Matthews, and French, King and Minami, the number of bearing acres in the current period is simply the number of bearing acres in the previous year less net removals in the current year.

Net removals are from new plantings coming into production less the acreage removed from the earlier season. Acreage planted with standard cultivars can take as long as nine to ten years to come into full production. However, dwarf and semi-dwarf trees come into full production as early as four to five years following planting. New plantings are a function of the expected profitability of the industry. This profitability depends on the price received for apples and the cost of producing these apples. The profitability of alternative opportunities for the acreage, such as other agricultural products or housing developments, may affect the number of new acres planted. However, it is difficult to isolate all of the alternative opportunities that may be available to apple producers. Furthermore, these opportunities vary between region and over time. A certain portion of bearing acreage is removed each year due to old age, lower than capacity production or to make room for other crops or new apple plantings.

Detailed data on removals, new plantings, and age class of apple acreage would allow for estimating relationships for new plantings, yields for each age class and removals of acreage. However, such detailed data are not often available. Hence, it is difficult to estimate all these relationships econometrically. For this model, bearing acreage was specified as a function of lagged acreage and measures of profitability. To reflect the delay between producers' planting decisions and acreage production, lagged three year moving averages of average grower price and the index of the prices paid by growers were used to capture producers' profitability.

The augmented Dickey-Fuller test indicated the existence of a unit root in the variable bearing acreage. Following Maddala (pages 258–64 and 582–92) the model was respecified in first differences. The change in bearing acres is specified as a function of the changes in lagged three year moving averages of grower prices and the index of production costs. A linear time trend is included in the model to capture the increase in the change in bearing acres over the time period of study.

Bearing acres are equal to last year's acreage plus the change identified above. Yields, seen by equation (3), are a function of apple profitability and technological advances over time. The total quantity of apples produced is expressed by equation (4). Utilized production, defined by equation (5), is a fraction of total production since all apples may not be harvested or may be discarded for economic or other reasons.

Allocation Sector

Once apples are produced, they are allocated to the fresh and processed markets. This model specifies the actual quantity of a product allocated to a particular market as a function of the total supply and expected relative prices in each market. The most prevalent expectation theories used in economics are rational expectations (Muth) and adaptive expectations (Nerlove). The rational expectations model was considered inappropriate for the apple industry since the assumption that the complete economic structure of an industry is used by decision makers to form expectations was considered too encompassing. A modification of the adaptive expectations theory is used in the empirical model specification. The price from a previous period is substituted for each expected price. Current prices were deemed inappropriate in the model specification since most apple producers use contracted prices to determine allocation to alternative markets.

The allocation of apples to the fresh market, expressed as equation (6) in Table 1, is a function of total utilization, fresh price and a relative measure of the size of the current harvest. If the total utilization of apples were to increase, one would expect the fresh allocation to increase. An increase in the fresh price expected by producers would increase the quantity allocated to the fresh market, all else equal. If the year's utilized production relative to previous years' utilized production is large, a smaller quantity will be allocated to the fresh market and more would go to processed apples.

The allocation of apples to the processed market is expressed algebraically by equation (7). Processed apples can be diverted to five markets: canned, juice, dried, frozen and other. The predominant use of apples in the canning market is for apple sauce. However, apples are also used for pie fillings, apple butter and other canned products. Processed apples diverted to the juice market are used for apple juice, juice blends, cider, and vinegar. The dried market consists of those apples used for dried fruit. Frozen pies and other frozen products comprise the frozen market. The apples used in the other market are for products such as apple chips, apple breads, etc. The allocation of apples to each processed market is a function of the total apples allocated to the processed market and the expected price of the product relative to the expected price of all processed products where the previous apple price is substituted for the expected price. If the total supply of apples to the processed market increased, more apples would be diverted to each processed outlet. If the expected price of a particular processed product increased relative to the average of all processed products, one would anticipate a larger quantity allocated to that particular market.

In the apple industry, juice is often the residual claimant of processed apples. However, nearly fifty percent of all processed apples are utilized for juice. Hence, for this model the quantity of processed apples utilized for juice is modeled explicitly. Frozen apples are assumed to be the residual since they claim a relatively small portion of the processed apple market. The allocation of apples to the canned, juice, dried, and other markets is expressed by equations (8), (9), (10), and (11) respectively. Analysis of the data revealed a significant decrease over time in the quantity of apples allocated to the other market sector. To capture this effect, a trend variable was included in equation (11). The allocation to the frozen market is seen by equation (12).

Demand Sector

The final sector of the model identifies the demand for all apples in the United States. Following Waugh, inverse demand functions are specified as price dependent functions of the quantity utilized, quantities of other apple products, income and other variables that might shift the demand function. Economic theory suggests an inverse relationship between the price and own quantity of each apple product. The coefficients on other apple product quantities depend on whether the goods are substitutes or complements. If apple products are normal goods the coefficients on the income measure, PCED, should be positive. Fresh oranges, processed pears, and orange juice were in-

Table 1. U.S. Apple Industry Model 1971–1990*

SUPPLY

Bearing Acres

(1) $\Delta AB_t = -2.202 + 1.208\,\Delta PAD3_{t-2} - 0.310\,\Delta IPP3_{t-2} + 0.731\,T_t$ $\quad R^2 = 0.665 \quad DW = 2.609$

+(−1.373) (1.977) (−1.204) (6.057)

(2) $AB_t = AB_{t-1} + \Delta AB_t$

Yield

(3) $Y_t = 7.550 + 0.545\,PAD3_t + 0.424\,T_t$ $\quad R^2 = 0.693 \quad DW = 2.367$

(3.139) (3.371) (7.502)

Production and Utilization

(4) $QPT_t = AB_t * Y_t$

(5) $QPU_t = 0.99 * QPT_t$

ALLOCATION

Fresh

(6) $QPUF_t = 1383.919 + 0.603\,QPU_t + 26.424\,PFD_{t-1} - 2051.654\,QPUCOM3_t$ $\quad R^2 = 0.956 \quad DW = 1.203$

(2.770) (15.520) (1.674) (−2.551)

Processed

(7) $QPUP_t = QPU_t - QPUF_t$

Canned

(8) $QPUC_t = 502.244 + 0.146\,QPUP_t + 165.878\,PCD_{t-1}/PPD_{t-1}$ $\quad R^2 = 0.569 \quad DW = 1.833$

(3.622) (4.555) (1.997)

Juice

(9) $QPUJ_t = -1186.554 + 0.792\,QPUP_t + 180.947\,PJD_{t-1}/PPD_{t-1}$ $\quad R^2 = 0.938 \quad DW = 1.465$

(−5.963) (17.368) (1.195)

Dried

(10) $QPUD_t = -10.146 + 0.054\,QPUP_t + 53.261\,PDD_{t-1}/PPD_{t-1}$ $\quad R^2 = 0.410 \quad DW = 1.106$

(−0.167) (4.045) (1.337)

Other

(11) $QPUO_t = 24.245 + 0.036\,QPUP_t + 57.979\,POD_{t-1}/PPD_{t-1} - 8.894\,T_t$ $\quad R^2 = 0.518 \quad DW = 2.381$

(0.372) (2.107) (1.038) (−3.959)

Frozen

(12) $QPUR_t = QPUP_t - QPUC_t - QPUJ_t - QPUD_t - QPUO_t$

DEMAND

Fresh Demand

(13) $PFD_t = 5.251 - 1.651\,QUF_t + 0.739\,QUC_t - 0.676\,QUJ_t + 3.134\,QUD_t + 1.286\,QUR_t$ $\quad R^2 = 0.855 \quad DW = 1.768$

(0.558) (−6.005) (1.003) (−3.392) (1.897) (0.717)

$+ 4.425\,QUO_t + 0.090\,PCED_t + 0.237\,QUFO_t$

(1.752) (3.310) (0.995)

Canned Demand

(14) $PCD_t = -15.846 - 19.053\,QUF_t - 7.390\,QUC_t - 4.150\,QUJ_t + 92.312\,QUD_t + 72.580\,QUR_t$ $\quad R^2 = 0.944 \quad DW = 1.780$

(−0.216) (−7.600) (−1.081) (−1.911) (5.303) (3.266)

$+ 60.456\,QUO_t + 0.756\,PCED_t + 25.652\,QUCEP_t + 65.750\,D734_t$

(2.598) (2.910) (4.790) (7.319)

Juice Demand

$$(15)\ PJD_t = \underset{(-0.763)}{-88.761} - \underset{(-3.748)}{13.096}\,QUF_t + \underset{(1.147)}{11.826}\,QUC_t - \underset{(-3.619)}{10.030}\,QUJ_t + \underset{(2.406)}{55.938}\,QUD_t + \underset{(0.961)}{24.004}\,QUR_t \qquad R^2 = 0.799 \qquad DW = 2.065$$

$$+ \underset{(0.972)}{34.182}\,QUO_t + \underset{(2.680)}{0.982}\,PCED_t + \underset{(0.688)}{0.293}\,QUJO_t$$

Dried Demand

$$(16)\ PDD_t = \underset{(-0.487)}{-63.081} - \underset{(-4.638)}{18.180}\,QUF_t + \underset{(0.749)}{8.570}\,QUC_t - \underset{(-2.796)}{8.706}\,QUJ_t + \underset{(3.882)}{99.450}\,QUD_t + \underset{(1.097)}{30.691}\,QUR_t \qquad R^2 = 0.850 \qquad DW = 1.575$$

$$+ \underset{(2.857)}{112.883}\,QUO_t + \underset{(2.468)}{1.016}\,PCED_t$$

Other Demand

$$(17)\ POD_t = \underset{(-0.672)}{-96.446} - \underset{(-3.153)}{13.690}\,QUF_t + \underset{(0.521)}{6.601}\,QUC_t - \underset{(-2.513)}{8.668}\,QUJ_t + \underset{(3.108)}{88.213}\,QUD_t + \underset{(0.598)}{18.536}\,QUR_t \qquad R^2 = 0.641 \qquad DW = 2.451$$

$$+ \underset{(0.524)}{22.941}\,QUO_t + \underset{(2.345)}{1.069}\,PCED_t$$

Frozen Demand

$$(18)\ PRD_t = \underset{(0.393)}{53.244} - \underset{(-3.994)}{16.473}\,QUF_t + \underset{(0.124)}{1.498}\,QUC_t - \underset{(-3.194)}{10.412}\,QUJ_t + \underset{(3.319)}{90.092}\,QUD_t + \underset{(1.031)}{30.682}\,QUR_t \qquad R^2 = 0.878 \qquad DW = 2.129$$

$$- \underset{(-0.357)}{14.821}\,QUO_t + \underset{(2.403)}{1.037}\,PCED_t + \underset{(11.343)}{79.448}\,D734_t$$

PRICE RELATIONSHIPS

Processing

$$(19)\ PPD_t = \underset{(-4.027)}{-9.448} + \underset{(6.246)}{0.359}\,PCD_t + \underset{(7.197)}{0.467}\,PJD_t + \underset{(3.953)}{0.190}\,PRD_t + \underset{(1.861)}{0.082}\,PDD_t - \underset{(-1.516)}{0.058}\,POD_t \qquad R^2 = 0.998 \qquad DW = 2.558$$

Average Price

$$(20)\ PAD_t = \underset{(0.122)}{0.038} + \underset{(10.423)}{0.023}\,PPD_t + \underset{(17.493)}{0.555}\,PFD_t \qquad R^2 = 0.994 \qquad DW = 1.456$$

JUICE IMPORTS

$$(21)\ NIJ_t = \underset{(1.814)}{3.404} - \underset{(-1.630)}{2.460}\,PIJD_t - \underset{(-2.043)}{0.535}\,QPUJ_t/POP_t + \underset{(8.135)}{0.746}\,T_t \qquad R^2 = 0.898 \qquad DW = 1.300$$

Utilization

Fresh

$$(22)\ QUF_t = QPUF_t/POP_t + NIF_t$$

Canned

$$(23)\ QUC_t = QPUC_t/POP_t + NIC_t$$

Juice

$$(24)\ QUJ_t = QPUJ_t/POP_t + NIJ_t$$

Dried

$$(25)\ QUD_t = QPUD_t/POP_t + NID_t$$

Other

$$(26)\ QUO_t = QPUO_t/POP_t + NIO_t$$

Frozen

$$(27)\ QUR_t = QPUR_t/POP_t + NIR_t$$

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*Coefficient t statistics identified in parenthesis.

Table 2. U.S. Apple Industry Model Variable Definitions

AB	Bearing Acres	(thousand acres)
ΔAB	Change in Bearing Acres	(thousand acres)
D734	Dummy Variable for 1973–74	(1971–72 = 0, 1973–74 = 1, 1974–88 = 0)
IPP3	Three Year Average of Index of Prices Paid by Producers	(1982 = 100)
ΔIPP3	Change in IPP3	(1982 = 100)
NIC	Net Imports—Canned	(pounds/person)
NID	Net Imports—Dried	(pounds/person)
NIF	Net Imports—Fresh	(pounds/person)
NIJ	Net Imports—Juice	(pounds/person)
NIO	Net Imports—Other	(pounds/person)
NIR	Net Imports—Frozen	(pounds/person)
PAD	Average Grower Price—All	(1982 cents/pound)
PAD3	Three Year Average of Previous PAD	(1982 cents/pound)
ΔPAD3	Change in PAD3	(1982 cents/pound)
PCD	Average Grower Price—Canned	(1982 $/ton)
PCED	Personal Consumption Expenditure for Food	(billion 1982$)
PDD	Average Grower Price—Dried	(1982 $/ton)
PFD	Average Grower Price—Fresh	(1982 cents/pound)
PIJD	Average Price—Juice Imports	(1982 $/gallon)
PJD	Average Grower Price—Juice and Cider	(1982 $/ton)
POD	Average Grower Price—Other	(1982 $/ton)
POP	Population	(million)
PPD	Average Grower Price—Processing	(1982 $/ton)
PRD	Average Grower Price—Frozen	(1982 $/ton)
QPT	Total Production	(million pounds)
QPU	Utilized Production	(million pounds)
QPUC	Canned Utilization	(million pounds)
QPUCOM3	Comparison of Current QPU to Three Year Average	(dimensionless)
QPUD	Dried Utilization	(million pounds)
QPUF	Fresh Utilization	(million pounds)
QPUJ	Juice and Cider Utilization	(million pounds)
QPUO	Other Utilization	(million pounds)
QPUP	Processed Utilization	(million pounds)
QPUR	Frozen Utilization	(million pounds)
QUC	Per Capita Utilization with Net Imports—Canned	(pounds/person)
QUCEP	Per Capita Utilization of Processed Pears	(pounds/person)
QUD	Per Capita Utilization with Net Imports—Dry	(pounds/person)
QUF	Per Capita Utilization with Net Imports—Fresh	(pounds/person)
QUFO	Per Capita Utilization of Fresh Oranges	(pounds/person)
QUJ	Per Capita Utilization with Net Imports—Juice	(pounds/person)
QUJO	Per Capita Utilization of Frozen Concentrated Orange Juice	(pounds/person)
QUO	Per Capita Utilization with Net Imports—Other	(pounds/person)
QUR	Per Capita Utilization with Net Imports—Frozen	(pounds/person)
T	Time Trend	(1971 = 1)
Y	Yield	(thousand pounds/acre)

cluded in the demand relationships for fresh, canned, and juice apples, respectively. The demand for canned, and frozen apples shifted in 1973–74 due to increased transportation and processing costs resulting from a rise in energy costs. Demand equations can be seen by equations (13) through (18) in Table 1.

Pricing Relationships, Imports and Utilization

A relationship is specified for determining a price for all processed products by equation (19). The price of all apple products is expressed as a function of the price in the fresh market and the average processed price, as seen by equation (20).

It is unreasonable to assume juice imports are exogenous and will remain stable following the period of study. Hence, a stochastic relationship, equation (21), identifying the quantity of juice imports was specified as a function of the average price of juice imports, per capita domestic utilization of juice and cider, and a trend term. The trend term was included to capture the increase in juice imports over time not accounted for by the other variables in the equation.

The final model equations (22) through (27) describe total utilization of each apple product where utilization depends on the domestic allocation to that market and the net imports of that product type.

MODEL ESTIMATION

All equations in the model are assumed to be linear in the parameters. The supply sector, identifying the change and level of bearing acres, yield, total production and utilized production, are usually known at the beginning of the crop year and are independent of the allocation of the product to alternative outlets. Furthermore, it is assumed the allocation of the products is independent of the demands for each product, the pricing relationships, and the demand for juice imports. Consequently, each model sector was considered independent of the other model sectors in the estimation process. Hence, the model was estimated as a block recursive system. Zellner's seemingly unrelated regression method (Kmenta) was chosen to estimate each model sector since the random error terms within each block are related.

Due to the independence of the pricing relationships, equations (19) and (20), they were estimated by ordinary least squares. The juice import function, equation (21), was also estimated by ordinary least squares. The demand for imports is assumed to be determined after the allocation of the processed product to the juice market occurs.

All model equations have coefficients consistent with the hypothesized signs and of reasonable magnitudes with a few exceptions. The demand equations for dried, other and frozen apple products suggest a positive own price relationship, contrary to economic theory. Equation R^2's are reasonable and Durbin-Watson statistics indicate either no first order autocorrelation or are inconclusive. LM tests for autocorrelated disturbances indicated no autocorrelation at the first, second, third and fourth order for any of the model equations (Maddala). Ex post forecasting indicated the 1991 observed values of all endogenous variables lie within the 95 percent confidence intervals determined by the models' forecasts with four exceptions: change in bearing acres, fresh price, juice price and dried price. The 1991 change in bearing acres was actually a decrease while the model predicted an increase in acreage. The decrease in acreage was only the second reduction in bearing acreage since 1975. The 1991 apple crop yielded record high prices and the value of apple production was up 22 percent from the previous year. The 1991 fresh price was 16 percent greater than the 1990 price, while the 1991 juice and dried fruit prices were 40 percent and 63 percent greater than the 1990 prices respectively (USDA 2). It is too early to tell if 1991 was an unusual year or if a structural change occurred in the industry that is not accounted for in the model specification.

Demand and supply elasticities of variables significant at the ten percent level are evaluated at the mean of the data set and at 1990, the last period in the data set. As seen in Table 3, the acreage elasticity ($\epsilon_{\Delta AB_t PAD3_{t-2}}$) indicates that the response of the change in apple acreage to a lagged three year moving average of apple prices is elastic. Fresh and canned allocation elasticities are inelastic. The fresh allocation elasticity ($\epsilon_{QPUF_t PFD_{t-1}}$) is nearly zero, supporting the notion that fresh supplies are largely pre-determined. All supply elasticities are consistent with those found by Tomek.

Demand flexibilities suggest the demands for fresh apples ($f_{PFD_t QUF_t}$) and apple juice ($f_{PJD_t QUJ_t}$) are inelastic. French found the elasticity for all apples to be -1.19. Tomek estimated the own price elasticities for fresh, canned and other apples to be -0.81, -1.21 and -0.76 respectively. Huang estimated fresh apple demand to be inelastic with a measure of -0.20. Baumes and Conway found flexibilities for fresh and processed apples to be -0.36 and -0.69, respectively. Hayward et al.'s estimate of the flexibility for all apples was -1.59. Miller's price elasticity for national apple demand was -0.59. While there is some variation among the elasticity and flexibility measures, those estimated in this study are within the range of other studies.

All apple products are normal goods as indicated by their expenditure flexibilities. These results contradict Huang's estimate of the expenditure elasticity of apples to be -0.35, implying an inferior good.

Cross-price flexibilities estimated with this study suggest that fresh apples and apple juice ($f_{PFD_t QUJ_t}$ and $f_{PJD_t QUF_t}$) are substitutes. Yet, fresh apples and dried apples ($f_{PFD_t QUD_t}$), fresh apples and other apple products ($f_{PFD_t QUO_t}$) juice and dried apples ($f_{PJD_t QUD_t}$), and juice and dried apple products ($f_{PJD_t QUD_t}$) are complements. Fresh apples and juice are substitutes for canned apples ($f_{PCD_t QUF_t}$, $f_{PCD_t QUJ_t}$), while dried apples, other apple products, and frozen products are complements for canned apples ($f_{PCD_t QUD_t}$, $f_{PCD_t QUO_t}$, $f_{PCD_t QUR_t}$). Fresh apples and juice are substitutes for dried, other, and frozen apple products ($f_{PDD_t QUF_t}$, $f_{PDD_t QUJ_t}$, $f_{POD_t QUF_t}$, $f_{POD_t QUJ_t}$, $f_{PRD_t QUF_t}$, $f_{PRD_t QUJ_t}$). Dried apple products are complements for other products and frozen apples ($f_{POD_t QUD_t}$, $f_{PRD_t QUD_t}$). Tomek found other processed apples to be substitutes for fresh apples and for canning apples.

MODEL FORECASTS

A common means of analyzing the impacts of exogenous changes on the performance of an indus-

Table 3. Elasticities and Flexibilities for Significant Variables in the U.S. Apple Industry Model*

		Mean	1990 Values
Supply Sector			
Bearing Acres	$\epsilon_{\Delta AB_t,PAD3_{t-2}}$	3.678	1.837
Yield	$\epsilon_{Y_t,PAD3_t}$	0.355	0.237
Allocation			
Fresh	$\epsilon_{QPUF_t,PFD_{t-1}}$	0.097	0.052
Canned	$\epsilon_{QPUC_t,PCD_{t-1}}$	0.094	0.082
Demand			
Fresh	f_{PFD_t,QUF_t}	−1.834	−2.057
	f_{PFD_t,QUJ_t}	−0.520	−0.856
	f_{PFD_t,QUD_t}	0.189	0.164
	f_{PFD_t,QUO_t}	0.132	0.075
	$f_{PFD_t,PCED_t}$	2.196	2.593
Canned	f_{PCD_t,QUF_t}	−2.406	−2.988
	f_{PCD_t,QUJ_t}	−0.362	−0.660
	f_{PCD_t,QUD_t}	0.036	0.035
	f_{PCD_t,QUR_t}	0.472	0.702
	f_{PCD_t,QUO_t}	0.205	0.129
	$f_{PCD_t,PCED_t}$	2.094	2.739
	$f_{PCD_t,QUCEP_t}$	0.698	0.802
Juice	f_{PJD_t,QUF_t}	−2.282	−2.914
	f_{PJD_t,QUJ_t}	−1.207	−2.264
	f_{PJD_t,QUD_t}	0.528	0.522
	$f_{PJD_t,PCED_t}$	3.756	5.050
Dried	f_{PDD_t,QUF_t}	−2.567	−3.787
	f_{PDD_t,QUJ_t}	−0.849	−1.840
	f_{PDD_t,QUD_t}	0.761	0.868
	f_{PDD_t,QUO_t}	0.428	0.321
	$f_{PDD_t,PCED_t}$	3.146	4.888
Other	f_{POD_t,QUF_t}	−2.039	−2.493
	f_{POD_t,QUJ_t}	−0.891	−1.601
	f_{POD_t,QUD_t}	0.712	0.673
	$f_{POD_t,PCED_t}$	3.493	4.498
Frozen	f_{PRD_t,QUF_t}	−1.837	−2.479
	f_{PRD_t,QUJ_t}	−0.802	−1.590
	f_{PRD_t,QUD_t}	0.545	0.568
	$f_{PRD_t,PCED_t}$	2.538	3.606
Price Relationships			
Processing	η_{PPD_t,PCD_t}	0.412	0.429
	η_{PPD_t,PJD_t}	0.389	0.393
	η_{PPD_t,PRD_t}	0.247	0.236
	η_{PPD_t,PDD_t}	0.084	0.074
Average	η_{PAD_t,PPD_t}	0.242	0.215
	η_{PAD_t,PFD_t}	0.755	0.773

*Significant at the $\alpha = 10$ percent level.

try is through the use of dynamic deterministic simulation analysis (French and Willett; Nuckton, French and King). The user can determine the impacts of individual changes on the industry with a series of simulations that isolate the changes.

First, a base case is established. In the base projections, it is assumed that (1) population continues to increase at a rate of 1.02 percent per year, the average growth rate for the last five years of the data set, (2) income increases at a rate of 1.01 percent per year, the average growth rate for the last five years of the data set, (3) per capita net imports of fresh, canned, dried, frozen and other apple products remain at their 1990 levels, and (4) any long term changes in the industry reflected by trend variables in the model continue for the duration of the analysis. The model is allowed to determine the acreage, yields, quantities produced and allocated to each apple product, the prices of the apple products and the net imports of juice products. The base case is used as a means of comparison with other simulations. It provides a benchmark if there were no other changes in the industry.

The base projections of selected model variables, seen in Table 4, indicate an increase in bearing acres (AB) from a 1990 value of 485.5 thousand acres to 540.4 thousand acres in the fifth year of the simulation. Yield (Y) varies between 20.4 and 21.5 thousand pounds per acre. Total apple production (QPT) appears to be cyclical with increases in the first, third and fifth year of the simulation. The fluctuation in yields and total apple production is generated by the lags inherent in the system. When prices are high, there is economic incentive to plant more acres and increase yield on existing acreage. Furthermore, after a time lag, more apples are allocated to each product market. An increase in allocation puts downward pressure on product prices which decreases the change in bearing acreage, yields, and production. These drops place upward pressure on market prices. The fluctuations can be seen in recent industry data and are captured by the estimated relationships of the model.

With the increase in apple production in the first year, more apples are allocated to the fresh (QPUF) and processed markets (QPUP). The percent of processed apples used for juice (QPUJ) varies from 55.7 percent to 56.9 percent. Some of the variation in juice apples comes from the canned market (QPUC), as that share of total processed products varies from 29.9 percent to 32.0 percent. Processed apple prices (PPD) and fresh apple prices (PFD) are cyclical during the simulation. The ratio of fresh prices (PFD) to processed prices (PPD) averages 0.21. The quantity of juice imports (NIJ) varies between between 11.5 and 11.8 pounds per person in response to population increases, acreage increases, production fluctuations, and price changes.

The first scenario maintains the assumptions of the base case. However, the acreage devoted to apples is held at 1990 levels. Historically, apple bearing acreage decreased until 1975 when it reached a low of 395.6 thousand acres. Since that time acreage increased an average of 1.5 percent per year. It is questionable if bearing acreage will or can continue to increase at that rate in the future. Results for this no growth in bearing acreage scenario suggest that production is curtailed leading to stronger fresh and processed apple prices. Less product is allocated for juice causing higher juice imports.

The second scenario combines the assumptions of the base case with acreage held constant and the per capita quantity of fresh exports increasing 10 percent in 1991. The increase in fresh apple exports, from 2.270 pounds per person to 2.497 pounds per person in the first and subsequent years of the simulation, yields an increase in total production and the allocations to the fresh and processed markets. Prices of fresh and processed apple products are stronger.

In the third scenario acreage is held at 485.5 thousand acres, the price of juice imports decreases 10 percent in the first year of the simulation, the deflated import price of juice decreases from \$0.559 per gallon to \$0.503 per gallon. This decrease in juice price follows the general trend of the per unit value of juice imports since 1979. In 1979 juice imports reached a peak price of \$1.28 per gallon. Since that time the price has decreased an average of 5.1 percent per year. This scenario generates a decrease of more than 11 million pounds in total apples produced. Fewer apples are allocated to the fresh and processed markets and per capita juice imports increase.

In the final scenario the base case assumptions are coupled with acreage held at 1990 levels, a 10 percent increase in per capita fresh exports, and a 10 percent decrease in juice import prices in the first year of the simulation. As expected, the constant acreage provides some limits on apple production and the increase in fresh exports generates demand for fresh apples, increases the quantity allocated to the fresh market, and strengthens the price of fresh apples. The lower price of juice imports leads to an increase in the quantity of juice imported and a decrease in the quantity of processed apples allocated to the juice market. Furthermore, a decrease in the juice import price weakens the price received for juice and the average price for all apple products.

SUMMARY AND CONCLUSIONS

The dynamic national apple industry model presented here includes relationships for the change in bearing acres, production, utilization and allocation to the fresh, canned, frozen, juice, dried and other markets. Demands for each of the markets are modeled. Data from 1970 through 1990 are used in the estimation of the model. Zellner's seemingly unrelated regression procedure is used since each model sector was considered independent of the other model sectors.

Demand and supply elasticities evaluated at the mean of the data set indicate that changes in acreage are elastic with respect to lagged prices. Fresh and canned products supply elasticities are inelastic. Demand flexibilities suggest the demand for fresh apples and apple juice are inelastic. All apple products are normal goods as indicated by their income flexibilities. Cross-price flexibilities sug-

Table 4. Forecasts Using the U.S. Apple Industry Model

Scenarios*	Base	1	2	3	4
	Population Income	Population Income Acreage	Population Income Acreage Fresh Exports	Population Income Acreage Import Price	Population Income Acreage Fresh Exports Import Price
ΔAB					
Year 1	11.9	0.0	0.0	0.0	0.0
2	9.8	0.0	0.0	0.0	0.0
3	12.8	0.0	0.0	0.0	0.0
4	9.5	0.0	0.0	0.0	0.0
5	11.0	0.0	0.0	0.0	0.0
AB					
Year 1	497.3	485.5	485.5	485.5	485.5
2	507.1	485.5	485.5	485.5	485.5
3	520.0	485.5	485.5	485.5	485.5
4	529.4	485.5	485.5	485.5	485.5
5	540.4	485.5	485.5	485.5	485.5
Y					
Year 1	21.5	21.5	21.5	21.5	21.5
2	20.7	20.8	20.9	20.8	20.9
3	20.6	20.9	21.0	20.9	21.0
4	19.9	20.4	20.5	20.4	20.5
5	20.3	21.0	21.0	20.9	21.0
QPT					
Year 1	10694.0	10438.8	10438.8	10438.8	10438.8
2	10506.6	10106.0	10132.2	10099.1	10125.3
3	10729.7	10139.8	10183.6	10128.1	10171.9
4	10537.2	9897.9	9956.2	9882.3	9940.7
5	10981.9	10175.1	10218.3	10163.5	10206.7
QPUF					
Year 1	6026.9	5908.2	5908.2	5908.2	5908.2
2	5813.6	5628.9	5650.9	5623.3	5645.3
3	6031.9	5740.4	5768.3	5733.2	5761.1
4	5926.7	5607.1	5643.8	5597.5	5634.3
5	6174.4	5760.4	5791.3	5752.3	5783.2
QPUP					
Year 1	4566.2	4432.0	4432.0	4432.0	4432.0
2	4593.7	4381.6	4385.5	4380.4	4384.3
3	4596.4	4303.6	4319.1	4299.2	4314.8
4	4511.0	4197.3	4218.3	4191.4	4212.5
5	4703.8	4318.6	4330.5	4315.2	4327.1
QPUC					
Year 1	1366.7	1347.2	1347.2	1347.2	1347.2
2	1471.7	1424.4	1417.9	1429.2	1422.2
3	1411.4	1363.7	1365.6	1364.7	1366.5
4	1409.0	1351.0	1353.0	1352.1	1354.1
5	1419.5	1357.7	1359.0	1358.6	1359.9
QPUJ					
Year 1	2581.2	2474.9	2474.9	2474.9	2474.9
2	2556.6	2393.7	2399.1	2390.1	2395.7
3	2594.7	2358.8	2369.8	2354.7	2365.7
4	2519.0	2269.8	2286.4	2264.1	2280.7
5	2677.4	2369.3	2378.6	2365.7	2375.0
QPUD					
Year 1	285.7	278.4	278.4	278.4	278.4
2	275.5	264.4	266.2	263.9	265.7
3	292.9	272.3	272.8	272.2	272.7
4	285.9	263.6	264.8	263.3	264.5
5	296.7	270.3	271.2	270.1	271.0
QPUO					
Year 1	68.7	63.9	63.9	63.9	63.9
2	93.9	80.3	78.2	80.7	78.5
3	91.5	72.8	71.9	73.0	72.0

Table 4. Forecasts Using the U.S. Apple Industry Model (continued)

Scenarios*	Base Population Income	1 Population Income Acreage	2 Population Income Acreage Fresh Exports	3 Population Income Acreage Import Price	4 Population Income Acreage Fresh Exports Import Price
4	91.0	67.9	67.7	67.9	67.6
5	91.2	67.9	67.9	67.8	67.8
QPUR					
Year 1	263.8	267.5	267.5	267.5	267.5
2	195.9	218.8	224.2	216.5	222.3
3	205.9	236.0	239.1	234.5	237.8
4	206.1	245.0	246.4	244.1	245.6
5	219.0	253.5	253.9	253.0	253.5
PFD					
Year 1	9.34	10.03	10.41	9.94	10.32
2	11.76	12.76	12.98	12.71	12.93
3	11.10	12.69	12.89	12.65	12.84
4	12.51	14.19	14.34	14.16	14.31
5	11.74	13.98	14.17	13.94	14.13
PCD					
Year 1	72.58	80.13	84.47	72.56	83.90
2	75.35	90.94	95.46	89.92	94.55
3	75.95	97.20	100.19	96.77	99.79
4	88.54	112.83	115.10	112.60	114.89
5	83.36	112.07	114.51	111.85	114.29
PJD					
Year 1	23.57	28.83	31.81	27.45	30.43
2	41.09	42.21	51.28	48.13	50.20
3	37.49	50.15	51.89	49.13	50.87
4	49.08	62.65	63.96	61.75	63.06
5	44.57	62.26	63.83	61.29	62.86
PDD					
Year 1	27.35	32.34	36.47	31.14	35.28
2	52.63	59.17	61.84	58.28	60.96
3	48.69	58.73	60.97	58.03	60.25
4	61.50	71.75	73.70	71.11	73.05
5	55.25	70.56	72.85	69.82	72.11
POD					
Year 1	58.23	63.11	66.22	61.92	65.03
2	73.59	81.42	83.92	80.40	82.92
3	73.39	84.71	86.55	83.87	85.71
4	84.73	97.00	98.50	96.26	97.76
5	81.38	97.54	99.27	96.73	98.46
PRD					
Year 1	72.37	80.11	83.86	78.68	82.43
2	81.86	96.15	99.75	94.69	98.35
3	82.21	102.33	104.72	101.22	103.62
4	95.87	118.42	120.17	117.50	119.25
5	90.72	118.09	120.11	117.10	119.12
PPD					
Year 1	40.26	47.02	50.84	45.87	49.69
2	52.43	64.62	67.97	63.46	66.86
3	50.72	68.26	70.68	67.41	69.84
4	63.64	83.13	84.96	82.44	84.28
5	58.38	82.48	84.56	81.75	83.83
PAD					
Year 1	6.16	6.70	6.99	6.62	6.92
2	7.78	8.62	8.82	8.56	8.76
3	7.38	8.66	8.83	8.62	8.78
4	8.45	9.84	9.97	9.81	9.93
5	7.90	9.71	9.86	9.67	9.82

Table 4. Forecasts Using the U.S. Apple Industry Model (continued)

Scenarios*	Base	1	2	3	4
	Population Income	Population Income Acreage	Population Income Acreage Fresh Exports	Population Income Acreage Import Price	Population Income Acreage Fresh Exports Import Price
NIJ					
Year 1	11.511	11.735	11.735	11.873	11.873
2	11.617	11.957	11.946	12.102	12.090
3	11.593	12.080	12.057	12.775	12.203
4	11.801	12.311	12.277	12.460	12.426
5	11.533	12.156	12.137	12.301	12.282

*Population = Increase of 1.02%/year
Income = Increase of 1.01%/year
Acreage = Held at 1990 levels
Import Price = Fixed 10% decrease in first year of simulation
Fresh Exports = Fixed 10% increase in first year of simulation

gest that juice and fresh apples are substitutes for most products while dried, frozen and other apple products are complements.

Simulation analyses were used to analyze the impacts of exogenous changes on the performance of the apple industry. The base case assumes that (1) population continues to increase at a rate consistent with the last five years of the sample, (2) income increases at a rate consistent with the last five years of the sample, (3) per capita net imports of all apple products, with the exception of juice, remain at 1990 values, and (4) any long term changes in the industry reflected by trend variables in the model continue for the duration of the analysis.

The base case was compared with four different scenarios where either acreage was assumed to remain at 1990 levels, fresh exports were increased 10 percent in the first year of the simulation, and/or the price of juice imports decreased 10 percent in the first year of the simulation. A comparison of the base case and the final simulation where acreage was held constant, fresh exports increased 10 percent and juice import prices decreased 10 percent suggests that there will be a 7 percent decrease in total production in the fifth year of the simulation. A larger percent of the crop is allocated to the fresh market in the last scenario. All prices strengthen with the fresh price 20.4 percent higher and processed product prices 43.6 percent higher than in the base case. Per capita juice imports are 6.5 percent greater in this simulation.

All of these scenarios suggest that constant acreage provides limits on apple production and thus strengthens prices of apple products. The increase in fresh exports generates demand for fresh apples, increases the quantity allocated to the fresh market and strengthens the price of fresh apples. The lower price of juice imports leads to an increase in the quantity of juice imported and a decrease in the quantity of processed apples allocated to the juice market. Furthermore, a decrease in the import price weakens the juice price and the average price of all apple products.

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