A Regional Econometric Model of U.S. Apple Supply and Demand

by

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Abstract

An econometric model of U.S. apple supply and demand is estimated using annual data for 1971-1997. Supply is arranged into four geographical regions, the Northwest, the Southwest, the Central, and the East. The structural model consists of five component: supply, allocation between fresh and processed utilization, pricing, demand and net imports. Estimated supply elastisticities illustrate regional differences in growers' ability to respond to market changes.

Key words: apple, econometrics, regional, three-stage least square.

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Introduction

Estimation of consumer and producer surplus changes that are caused by technology shifts requires knowledge of demand and supply elasticities in the markets in questions. Because apple production systems are very heterogeneous across the United States, growers' abilities to respond to technology changes and market forces differ widely. To capture the dispersion of responses, estimates of elasticities are needed for the different grower groups. To this end, a model of U.S. apple production was estimated at a regional level.

Several econometric models of the U.S. apple industry exist in the literature, but none of them provides regional elasticity estimates that are suitable for our modeling effort. Willett (1993) estimates an econometric model of the apple industry with a focus on the demand side. Supply is estimated at the aggregated U.S. level. Baumes and Conway (1984) also estimate a model at the aggregated U.S. level, and use their model to demonstrate the effects of a hypothetical pesticide ban. However, their model does not allow for the analysis of regional effects.

Hossain (1993) estimates a model of U.S. apple industry for two regions, dividing the United States into the West/Central (excluding Michigan) and the East (incl. Michigan). The model is specified at the wholesale-retail level. Supply is considered to be fixed in any given period and the model is not useful for the estimation of short-run or long-run production impacts because growers can only adjust to price changes by reallocating fruit from fresh to processed consumption. Chaudhry (1988) estimates a regional model, concentrating on allocation decisions to the fresh and processing market and to the month of sale within a given year. He models production as exogenous in any given year.

Fuchs, Farish, and Bohall (1974) and Dunn and Garafola (1986) simulate regional demand and supply impacts via mathematical programming models. While these models are the only ones whose regional specification would allow modeling regional impacts as desired, mathematical models need a large amount of information and this data is hard to obtain when seeking long-run impacts. Miller (1976) estimates regional price response functions for eight regions of the U.S. in a model of regional competition. He models supply as given.

In general it can be said that although several models of the apple industry exist, most of them are dated and interest is mostly focused on short-term allocation decisions or structural changes in product demand. None of these models is appropriate for the modeling of regional impacts of technology shifts because supply is usually taken as given. The results in this paper show that production adjustments differ across regions and that this heterogeneity ought to be acknowledged when conducting welfare assessments of technology changes in the apple industry.

The Model

The structural model is organized into five components: supply, allocation, pricing, demand, and net imports. We divide the United States into four apple production regions, the Northwest, the Southwest, the Central, and the East, as described in table 1, and for each region the total supply and the allocation between markets for fresh and processed utilization are modeled. The demand and net import equations on the other hand are set at the aggregated U.S. level. To link the regional supply components with the demand component, regional pricing equations are introduced that translate U.S. level prices into regional prices. In this section we describe the specification of the model component by component.

Supply

In each production region, supply decisions for a crop are divided into a decision about acreage to be planted and a decision about planned yields. Apple orchards can have a lifetime of several decades and acreage decisions in apple production are expected to be inelastic in the short run. Following French, King, and Minami, we model the change in bearing acreage in region j and year t, ΔAB_t^j, rather than the total bearing acreage, AB_t^j, directly and it is described as a function of past input and output prices, $IPP3_t$ and $PA3_t^j$.

Yield per acre, Y_t^j, is modeled as a function of expected price and a time trend, *T*, that captures changes in the production technology. Specifically, price expectations are modeled as adaptive expectations and approximated by a three-year moving average of past average prices received, $PA3_t^j$.

Total production for a region, QPT_t^j, is the product of yield and bearing acreage. The general form of the functions describing the supply sector for each region can be summarized as:

$$\Delta AB_t^j = a_{10}^j + a_{11}^j PA3_{t-3}^j / IPP3_{t-3} + \varepsilon_{1t} \quad (1)$$

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

$$Y_t^j = a_{20}^j + a_{21}^j PA3_{t-1}^j + a_{22}^j T + \varepsilon_{2t} \quad (3)$$

$$QPT_t^j = AB_t^j \cdot Y_y^j \quad (4)$$

where subscripts *t* signify the time index and superscripts *j* denote the region and $IPP3_t$ is the index for prices paid by farmers on the U.S. basis. Greek letters signify error terms in the equations to be estimated and $a_{..}^j$ are the parameters to be estimated.

Allocation

The allocation equation estimates the amount of apples sold in the market for fresh apples, QPF_t^j. Explanatory variables include the price premium paid for fresh apples, i.e. the difference of prices paid for fresh and process apples, $PF_t^j - PP_t^j$, and total production in the current year, QPT_t^j. The coefficient to QPT_t^j indicates the share of total production above average total production allocated to fresh consumption, while the coefficient to $PF_t^j - PP_t^j$ measures the change of fresh utilization due to price incentives.

Produce allocated to the processing market is defined as the difference between total and fresh production, so that the allocation component of the model is described by

$$QPF_t^j = a_{30}^j + a_{31}^j (PF_t^j - PP_t^j) + a_{32}^j QPT_t^j + \varepsilon_{3t} \quad (5)$$

$$QPP_t^j = QPT_t^j - QPF_t^j \quad (6)$$

Demand

Regional production of fresh and processed apples is aggregated to the U.S. level at which the demand system estimates apple consumption per person in the form of inverse demand functions. The per capita quantities of consumption of fresh apples, QUF_t, and consumption of an alternative fresh fruit, e.g., fresh oranges, enters the estimation of the inverse demand for fresh apples, as do per capita personal food consumption expenditures, $PCEDC_t$. A time trend was also included. Alternative fruits were included to measure substitution effects or changes in taste parameters. The demand for processing apples is specified as a function of processed apple consumption, QUP_t, consumption of an alternative processed fruit, e.g., orange juice, and personal food consumption expenditures.

$$PF_t = d_{10} + d_{11}\, QUF_t + d_{12}\, QUFO_t + d_{13}\, PCEDC_t + d_{14} T + \eta_{1t} \tag{7}$$
$$PP_t = d_{20} + d_{21}\, QUP_t + d_{22}\, QUJO_t + d_{23}\, PCEDC_t + d_{24}\, T + \eta_{2t} \tag{8}$$

where $QUFO_t$ denotes fresh orange consumption, and $QUJO_t$ the consumption of orange juice.

Pricing

To link the regional supply sectors of the model to the national demand sector, regional fresh and processing prices are modeled as a linear function of the average U.S. price.

$$PF_t^{\,j} = b_{10} + b_{11} PF_t + \beta_{1t} \tag{9}$$
$$PP_t^{\,j} = b_{20} + b_{21} PP_t + \beta_{2t} \tag{10}$$

Our modeling approach is similar to that of Miller, who estimates a demand function for each region as a function of U.S. supply. Using linear pricing equation jointly with the inverse demand equations, we restrict the differences in the regional demand equations to linear transformations of a common national demand function.

Net Imports

Net imports for fresh and processed apples are modeled as a function of the U.S. price for the respective product, PF_t and PP_t, and the quantities of U.S. fresh and processed production, QPF_t and QPP_t. In addition, the per-unit values of net imports, PIF_t and PIP_t, was included; it is calculated as the value of net imports and exports over the respective total quantity. The equations are of the form:

$$NIF_t = e_{10} + e_{11}\, PF_t + e_{12}\, PIF_t + e_{13} QPF_t + e_{14} T + \mu_{1t} \tag{11}$$
$$NIP_t = e_{20} + e_{21} PP_t + e_{22}\, PIP_t + e_{23} QPP_t + e_{24} T + \mu_{2t} \tag{12}$$

Data

The model is estimated using data from 1971-97. The index of prices paid by farmers (IPP_t) is obtained from U.S. Department of Agriculture, Agricultural Statistics and the import and export data from the U.S. Department of Agriculture, Foreign Agricultural Trade of the United States. Production and consumption data are taken from several U.S. Department of Agriculture ERS/CED publications and Johnson. For the estimation all prices, including, IPP_t, are deflated by a GDP deflator (1992=100) taken from the economic report of the U.S. President.

Although apple production statistics are reported for all major production states, some statistics are incomplete for minor states. For the ten major apple producing states (Washington, Michigan, New York, California, Pennsylvania, Virginia, North Carolina, West Virginia, Oregon, and Ohio) that produce 92% of total U.S. apple production all necessary data are available. For some minor states, in which not all statistics are recorded continuously, missing values are filled in and we describe the procedures used in the process.

For bearing acreage, a quadratic trend curve is fitted through the available years of data and the predicted values are used to fill in missing values. The percentage of crop allocated to the fresh market is estimated using a linear regression of fresh production in the state with missing data on fresh allocation in other states of the same region in the same year. This method measures the average percentage going to the fresh market and captures average responses to market, weather, and pest conditions in the region.

Total production data are complete, and yield data are obtained by dividing total production by acreage. Average grower prices are also reported for all states. The price received for fresh apples is not available in every year for all states, and missing values are replaced by regional averages for the given year. The missing value for the processing price is calculated to ensure that the weighted average of processing and fresh prices results in the average price for the state.[1] It should be noted that, since the complete data accounts for more than 90% of U.S. production, filling in the missing data should not have significantly changed the results significantly.

Results

The system is estimated using three-stage least squares. For the supply side, apple production in the United States is segmented into four production regions: Northwest, Southwest, Central, and East and table 1 gives some production statistics for the four regions. The estimated model is presented in table 2 and the numbers in parentheses report t-values for the parameter estimates. Variable definitions are given in table 3. The variables IPP3, POP, T, QUFO, QUJO, QUFB, QUCPP, QUCEP, PCEDC, PIF, and PIP are used as instruments in the estimation. The R^2 values suggest a good fit and the Durbin-Watson statistics either reject the presence of first-order autocorrelation or are inconclusive.

Apple production technologies have significantly changed in the years over which the model is estimated. Large areas of land became available to apple production due to irrigation, particularly in the Columbia-River area in the Northwest. Because of this, the West has replaced the East as the largest apple-producing region of the United States. New varieties have been adopted, and a shift to high-density orchards occurred.

These changes cannot be explained solely by changes in input and output prices and even if they could, hardly any data on input costs are available for the apple industry. To model these structural shifts in the data, dummy variables are employed in the estimation process. Next, we will describe our results and explain any adjustments that are made to the general model outlined in the previous section.

Northwest

The acreage equation includes a dummy for the years 1986-87, when Washington experienced an unusually large increase in bearing acreage. The allocation equation suggests that 66% of the increases in total production are allocated to fresh consumption and that an increase in the price premium paid for fresh apples increases fresh production significantly. Looking at the regional pricing equations, we can conclude that prices are more variable in the Northwest than in the other regions, as the multiplicative term is greater than one.

Southwest

The equation for the acreage includes a dummy variable to account for sudden increases that occurred in the acreage of apple production in the late 1980s in California. This increase might have been caused by the large increase in prices for fresh apples after 1986. California experienced in the 1980s an increase in the acreage planted to the then new variety Fuji. The alar crisis of the 1980s might be another factor explaining these structural shifts.

In comparison to the Northwest, a smaller share of the above average production is allocated to the market for fresh apples, and increases in the premium for fresh apples causes a statistically significant adjustment in the allocation to the fresh market. Prices for fresh apples are less variable than they are in other regions.

Central

A dummy variable for years after 1981 is included in the acreage equation. It marks the year when the trend of decreasing acreage in Michigan was reversed and when Michigan started planting heavily towards processing apples. At the same time we experience an increase in the average yield level. Industry experts indicated to us that at this time returns in the apple industry were quite favorable and encouraged replanting of older orchards. Many of the then newly planted orchards are of improved technology (higher density) and yield a larger crop.

For the yield equation, the relationship between prices and yields seemed to change in the last two years of the data. We control for this change by including a dummy variable for 1996-97. During these years, imports of processed apples increased substantially, where most of these additional imports originate in China. We experience for instance at the same time a sudden drop in the price for processed apples in the Northwest from 7.5 ¢/lb. to 4.1 ¢/lb. More years of data would be needed to measure a structural adjustment or to establish that this is a temporary aberration.

East

Due to the growing competition from western states, acreage has been steadily declining in the East. Changes in acreage depend significantly on price developments, much more so here than they do in other regions. About 17% of above average total production are allocated to the fresh market.

General Supply Component

In general, the estimates of the yield equation show that the Northwest has benefited more from technological progress in the apple industry than any other region. After accounting for market changes, average yields increased by 698 lb./acre/year in the Northwest, compared with 229 lb./acre/year in the Southwest, 250 lb./acre/year in the Central, and 113 lb./acre/year in the East.

The allocation equations in all regions show that if total production increases, a smaller than average share of total production is allocated to fresh utilization, i.e., the average share of fresh production in the Northwest is 73.2% and 66% of an increase in total production are marketed as fresh. For the Southwest the average fresh production share is 38.5%, for the Central it is 50.6%, and for the East it is 43.4%.

Net Imports

Turning to the net import equations it is found that the home price level is significant in the determination of net imports of both fresh and processed apples. The per-unit value of imports, on the other hand, is significant in the fresh market but not so in the processed market. Low quantities of home production increase net imports, i.e., increase imports and/or lower exports.[2] Net imports respond more to home production in the processing sector than they do in the fresh sector. Both imports for fresh apples and processing apples increase over time but imports in the processing sector are increasing at a faster absolute rate. In fact, net imports are negative for fresh apples and positive for processed apples so that our model predicts a decreasing trade surplus in the fresh apple market and an increasing trade deficit in the processed apple markets given recent price and home production levels.

The estimates indicate that imports of processed apples are much more responsive to changes in the home market than it is the case for the fresh market. Both the responsiveness to the U.S. price level and the responsiveness to the quantity of home production are larger.

Demand

The demand equations show that demand for fresh and processed apples is decreasing in prices and increasing in income. The income coefficient is larger in the demand for fresh apples than for processed apples. Fresh oranges were used as the alternative fruits in the equation for fresh demand and orange juice as the alternative in the equation for processed demand. Other fruits such as fresh bananas, canned pears, and canned peaches were tested as additional or alternative substitutes but failed to improve the estimation.

Fresh oranges serve as substitutes for fresh apples. However, orange juice serves a complement of processed apples. Since increased apple juice consumption is the primary cause for the increased consumption of processed apples in general, we conclude that orange juice measures a change in taste towards higher juice consumption, a result that is also found in Willet.

Elasticity Estimation

Elasticities are calculated by first evaluating the system at the means of the data. Then U.S. level prices for fresh apples and/or processed apples are shocked by a constant over a five-year period. The changed quantities in the market are simulated forward separately for the supply and demand side and the elasticities for each year are calculated using the changed quantity in the specific year after the initial shock. Their value is reported for a one-year lag and five-year lag. Given the structure of the model, the elasticities for the first year after an exogenous change in output price can only include yield and allocation changes, while at a five-year lag acreage might adjust as well. For the demand and net import equations the model is static, hence elasticities are the same for all years.

We report two types of elasticities. Table 4 gives partial elasticities that measure immediate quantity responses following a change in prices, for instance $\in_{QPFNW,PF} = \partial \ln QPFNW / \partial \ln PF$ where QPPNW is held constant. Table 5 gives in addition elasticities for the overall production component of the model where fresh and processed production are allowed to adjust simultaneously, e.g., $\mathrm{E}_{QPFNW,PF} = d \ln QPFNW / d \ln PF$. Total supply response elasticities are not reported for the demand and net import component because those do not include cross terms.

A nonparametric bootstrap method of 1000 iterations was used to determine the statistical significance of the elasticity estimates and asterisks mark the elasticities that are significant at the 0.1 level. To implement the bootstrap the system is first estimated and predicted values are calculated for the sample period. A matrix of residuals is formed for the entire system, and we randomly draw with replacement residuals from this matrix. Adding the series of resampled residuals to the respective series of predicted values, a new data set of random-error-adjusted predicted values is formed. The system is reestimated using these adjusted predicted values and this procedure is repeated 1000 times. Elasticities are calculated for each estimation and their statistical significance is determined (Efron; Schroeder).

Supply responses are inelastic to price changes in the short run. The technology of apple production allows only for slow adjustments because newly planted orchards take several years to come into full bearing and yields can only be adjusted to a very limited extent. Although technology constrains growers to a relatively inelastic response in total production, they can also adjust by reallocating production between the fresh and processing sector if relative prices change.

Looking at the cross elasticities of supply for the combined supply responses (table 5), we can see that they are negative in all regions in the short run. The increase in average price due to the increase in the price for fresh or processed apples will induce an increase in yield and acreage. The change in relative prices will in addition cause the reallocation of crop to the utilization for which prices increase, and this reallocation outweighs the increase in total production in the short run. Turning to the long-run elasticities, the cross-price elasticity of processed production with respect to fresh price turns positive in the Northwest and Southwest, as now, given the increase in fresh price, total production will increase so much that both fresh and processed production increases.

Own-price demand elasticities for fresh and processing apples are -0.37 and -0.70, respectively, and the overall demand elasticity with respect to an increase in average price is -0.55. The demand for apples responds relatively inelastically to changes in prices. The income elasticity is 1.2 for fresh apples and 2.6 for processed apples.

Hossain reports own price demand elasticities of -0.81 and -0.94 for fresh and processed apples respectively. For his model, this gives a total demand elasticity of about -0.86, a higher elasticity of demand than our result. His income elasticities are, on the other hand, much lower with values of 0.04 and 0.43 for fresh and processed apples. He calculates short-term supply elasticities of 0.08 and 0.12 for fresh and processed apples that are smaller than ours. However, his model allows only for direct reallocation effects.

Our income elasticities are more in line with results of Baumes and Conway who report income elasticities of 1.07 and 0.73 for fresh and processed apples, respectively. Their demand elasticities are -1.14 and -1.17 respectively, resulting in a total demand elasticity of -1.15.

Conclusion

Elasticity estimates are obtained for supply and demand responses to price changes in the markets for fresh and processed apples. The supply elasticities are estimated for four production regions, and differences in growers' ability to respond to market changes are evident in these estimates. The resulting elasticity estimates are useful in the estimation of regional impacts that result from changes in the technological or economic environment.

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Notes

[1] List of filled in data: Acreage: Arizona (1984-88), Colorado (1984-92), New Mexico (1988-92), Utah (1984-92), Idaho (1984-92), Georgia (1988-89), Delaware (1985-92), Maryland (1984-92), Connecticut (1984-92), Maine (1984-92), Massachusetts (1984-92), New Hampshire (1984-92), Rhode Island (1984-92), Vermont (1984-92), Kentucky (1984-92), Illinois (1984-92), Indiana (1984-92), Iowa (1984-92), Kansas (1984-92), Minnesota (1984-92), Missouri (1984-92). Percentage of Fresh Production**:** Arizona (1978-88), Colorado (1975-76), New Mexico (1969-75,1980-86), Utah (1971), Georgia (1969-1997: replaced by regional mean), Delaware (1973-97: replaced by regional mean), Rhode Island (1969-97: replaced by regional mean), Arkansas (1969-97: replaced by regional mean), Kentucky (1969-76,1979-81), Tennessee (1969-70, 1972-1997: replaced by regional mean), Illinois (1975), Iowa (1969-73,1976,1978-97), Kansas (1974-76,1980,1989-97), Minnesota (1971,1973-75,1979-1997). Fresh Prices: Arizona (1978-88), Colorado (1975-76), New Mexico (1969-75,1980-86), Utah (1971), South Carolina (1969-72,1980,1982), Georgia (1969-1997), Delaware (1973-97), Rhode Island (1969-97), Arkansas (1969-97), Kentucky (1969-76), Tennessee (1969-70, 1972-1997), Illinois (1975), Iowa (1969-73,1976,1978-97), Kansas (1974-76,1980,1989-97), Minnesota (1971,1973-75,1979-1997).

[2] The United States produces 4,733 mill. metric tons or 9% of worldwide apple production (FAO, Production Yearbook, 1996). Exports amount to 0.6 mill. metric tons or 12% of the 5.2 mill. metric tons exported worldwide (FAO, Trade Yearbook, 1996).

Table 1. Production Regions, 1997 [a]

Region	States	Bearing Acreage (000 acres)	Total Production (mill. lb.)	Fresh Production (mill. lb.)	Average Price (c/lb.)	Fresh Price (c/lb.)	Processed Price (c/lb.)
Northwest	Washington, Oregon, Idaho	170.3	5270.0	3762.0	16.7	21.7	4.1
Southwest	Arizona, California, Colorado, Utah, New Mexico	50.5	1091.0	440.0	16.6	32.4	6.4
Central	Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, Tennessee, Wisconsin	92.6	1413.1	1050.1	13.2	20.3	7.3
East	Delaware, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, West Virginia,	140.6	2627.0	574.9	13.5	24.9	8.3
U.S.		**454.0**	**10401.1**	**5827.1**	**15.4**	**23.0**	**6.4**

[a] Numbers might not add up due to rounding.

Table 2. Estimation Results

Supply Sector

Northwest

$\Delta ABNW_t$ =	$-0.124 + 20.540\ PANW3_{t-3}/IPP3_{t-3} + 11.000\ D867$	R^2 =0.497
	(-0.059) (1.491) (8.951)	DW =1.276
$ABNW_t$ =	$ABNW_{t-1} + \Delta ABNW_t$	
YNW_t =	$7.192 + 0.674\ PANW3_{t-1} + 0.698\ T$	R^2 =0.523
	(2.054) (4.426) (8.805)	DW =1.695
$QPTNW_t$ =	$ABNW_t * YNW_t$	

Southwest

$\Delta ABSW_t$ =	$-2.821 + 22.290\ PASW3_{t-3}\ /IPP3_{t-3} + 4.834\ D879$	R^2 =0.471
	(-1.497) (1.521) (6.782)	DW =2.312
$ABSW_t$ =	$ABSW_{t-1} + \Delta ABSW_t$	
YSW_t =	$-0.165 + 1.065\ PASW3_{t-1} + 0.229\ T$	R^2 =0.513
	(-0.083) (8.818) (6.398)	DW =2.400
$QPTSW_t$ =	$ABSW_t * YSW_t$	

Central

ΔABC_t =	$-7.926 + 37.948\ PAC3_{t-3}/IPP3_{t-3} + 3.952\ D81$	R^2 =0.433
	(-3.883) (2.883) (6.965)	DW =1.324
ABC_t =	$ABC_{t-1} + \Delta ABC_t$	
YC_t =	$9.906 + 0.050\ PAC3_{t-1} + 0.250\ T - 4.730\ D967$	R^2 =0.316
	(3.227) (0.340) (3.907) (-5.026)	DW =2.383
$QPTC_t$ =	$ABC_t * YC_t$	

East

ΔABE_t =	$-11.659 + 79.046\ PAE3_{t-3}/IPP3_{t-3}$	R^2 =0.363
	(-4.911) (4.231)	DW =1.851
ABE_t =	$ABE_{t-1} + \Delta ABE_t$	
YE_t =	$13.567 + 0.071\ PAE3_{t-1} + 0.113\ T$	R^2 =0.350
	(10.405) (1.081) (4.087)	DW =1.841
$QPTE_t$ =	$ABE_t * YE_t$	

Table 2 (continued)

Allocation

Northwest

$QPFNW_t = -0.808 + 16.419\ (PFNW_t - PPNW_t) + 0.661\ QPTNW_t$ $\quad R^2 = 0.975$
(-0.007) (2.033) (44.637) $\quad DW = 2.437$

$QPPNW_t = QPTNW_t - QPFNW_t$

Southwest

$QPFSW_t = -128.253 + 8.251\ (PFSW_t - PFSW_t) + 0.354\ QPTSW_t$ $\quad R^2 = 0.878$
(-5.086) (5.414) (12.127) $\quad DW = 1.931$

$QPPSW_t = QPTSW_t - QPFSW_t$

Central

$QPFC_t = -357.647 + 28.488\ (PFC_t - PPC_t) + 0.493\ QPTC_t$ $\quad R^2 = 0.693$
(-3.366) (6.960) (9.603) $\quad DW = 2.372$

$QPPC_t = QPTC_t - QPFC_t$

East

$QPFE_t = 242.384 + 34.544\ (PFE_t - PPE_t) + 0.173\ QPTE_t$ $\quad R^2 = 0.627$
(2.336) (7.491) (4.652) $\quad DW = 1.730$

$QPPE_t = QPTE_t - QPFE_t$

Regional Price Determination

Northwest

$PFNW_t = -4.596 + 1.197\ PF_t$ $\quad R^2 = 0.881$
(-3.125) (17.833) $\quad DW = 1.794$

$PPNW_t = -4.923 + 1.535\ PP_t$ $\quad R^2 = 0.764$
(-5.376) (15.205) $\quad DW = 1.557$

$PANW_t = (QPFNW_t * PFNW_t + QPPNW_t * PPNW_t) / QPTNW_t$

Southwest

$PFSW_t = 15.260 + 0.460\ PF_t + 4.617\ D86$ $\quad R^2 = 0.533$
(5.809) (4.123) (5.970) $\quad DW = 2.133$

$PPSW_t = -2.758 + 1.364\ PP_t$ $\quad R^2 = 0.702$
(-2.673) (11.862) $\quad DW = 1.931$

$PASW_t = (QPFSW_t * PFSW_t + QPPSW_t * PPSW_t) / QPTSW_t$

Table 2 (continued)

Central		
$PFC_t =$	$1.794 + 0.916\ PF_t$	R^2 =0.718
	(0.875) (9.990)	DW=1.826
$PPC_t =$	$2.024 + 0.814\ PP_t$	R^2 =0.832
	(3.414) (12.787)	DW=2.446
$PAC_t=$	$(QPFC_t * PFC_t + QPPC_t * PPC_t)/ QPTC_t$	
East		
$PFE_t =$	$0.670 + 1.020\ PF_t$	R^2 =0.627
	(0.238) (8.077)	DW=1.270
$PPE_t =$	$2.731 + 0.688\ PP_t$	R^2 =0.872
	(6.398) (15.070)	DW=1.785
$PAE_t=$	$(QPFE_t * PFE_t + QPPE_t * PPE_t)/ QPTE_t$	
<u>Aggregation to U.S. Production</u>		
$QPF_t =$	$QPFNW_t + QPFSW_t + QPFC_t + QPFE_t$	
$QPP_t=$	$QPPNW_t + QPPSW_t + QPPC_t + QPPE_t$	
<u>Utilization</u>		
$QUF_t =$	$QPF_t/POP_t + NIF_t/POP_t$	
$QUP_t =$	$QPP_t/POP_t + NIP_t/POP_t$	
<u>Net Imports</u>		
$NIF_t =$	$3024.12 - 31.320\ PF_t - 579.324\ PIF_t - 0.632\ QPF_t + 23.779\ T$	R^2 =0.873
	(11.346) (-5.540) (-2.026) (-11.900) (3.688)	DW=0.941
$NIP_t =$	$2855.47 - 100.344\ PP_t - 23.190\ PIP_t - 0.758\ QPP_t + 172.664\ T$	R^2 =0.870
	(4.803) (-2.369) (-0.094) (-3.827) (9.229)	DW=1.424
<u>Demand</u>		
$PF_t =$	$24.401 - 3.202\ QUF_t - 0.059\ QUFO_t + 0.021\ PCEDC_t - 0.941\ T$	R^2 =0.650
	(2.281) (-7.947) (-0.514) (4.189) (-4.458)	DW=0.920
$PP_t =$	$-8.667 - 0.540\ QUP_t + 0.507\ QUJO_t + 0.009\ PCEDC_t - 0.316\ T$	R^2 =0.478
	(-1.155) (-5.989) (2.213) (3.237) (-2.509)	DW=1.747

Table 3. Definition of the Variables

$ABNW_t$	Bearing acreage in Northwest in year t	(000 acres)
$ABSW_t$	Bearing acreage in Southwest in year t	(000 acres)
ABC_t	Bearing acreage in Central in year t	(000 acres)
ABE_t	Bearing acreage in East in year t	(000 acres)
$\Delta ABNW_t$	Change in bearing acreage in Northwest from year t-1 to year t	(000 acres)
$\Delta ABSW_t$	Change in bearing acreage in Southwest from year t-1 to year t	(000 acres)
ΔABC_t	Change in bearing acreage in Central from year t-1 to year t	(000 acres)
ΔABE_t	Change in bearing acreage in East in year t-1 to year t	(000 acres)
YNW_t	Yield/acre in Northwest in year t	(000 lb./acre)
YSW_t	Yield/acre in Southwest in year t	(000 lb./acre)
YC_t	Yield/acre in Central in year t	(000 lb./acre)
YE_t	Yield/acre in East in year t	(000 lb./acre)
$QPTNW_t$	Total production in Northwest in year t	(mill. lb.)
$QPTSW_t$	Total production in Southwest in year t	(mill. lb.)
$QPTC_t$	Total production in Central in year t	(mill. lb.)
$QPTE_t$	Total production in East in year t	(mill. lb.)
$QPFNW_t$	Quantity marketed as fresh in Northwest in year t	(mill. lb.)
$QPFSW_t$	Quantity marketed as fresh in Southwest in year t	(mill. lb.)
$QPFC_t$	Quantity marketed as fresh in Central in year t	(mill. lb.)
$QPFE_t$	Quantity marketed as fresh in East in year t	(mill. lb.)
$QPPNW_t$	Quantity marketed as processed in Northwest in year t	(mill. lb.)
$QPPSW_t$	Quantity marketed as processed in Southwest in year t	(mill. lb.)
$QPPC_t$	Quantity marketed as processed in Central in year t	(mill. lb.)
$QPPE_t$	Quantity marketed as processed in East in year t	(mill. lb.)
QPF_t	U.S. fresh production in year t	(mill. lb.)
QPP_t	U.S. processed production in year t	(mill. lb.)
$PFNW_t$	Price received by growers for fresh apples in Northwest in year t	(¢/lb.)
$PPNW_t$	Price received by growers for processed apples in Northwest in year t	(¢/lb.)
$PANW_t$	Average price received by growers in Northwest in year t	(¢/lb.)
$PANW3_t$	Three-year average of $PANW_t$ based on periods t-2, t-1, t	(¢/lb.)
$PFSW_t$	Price received by growers for fresh apples in Southwest in year t	(¢/lb.)
$PPSW_t$	Price received by growers for processed apples in Southwest in year t	(¢/lb.)
$PASW_t$	Average price received by growers in Southwest in year t	(¢/lb.)
$PASW3_t$	Three-year average of $PASW_t$ based on periods t-2, t-1, t	(¢/lb.)

Table 3 (continued)

PFC_t	Price received by growers for fresh apples in Central in year t	(¢/lb.)
PPC_t	Price received by growers for processed apples in Central in year t	(¢/lb.)
PAC_t	Average price received by growers in Central in year t	(¢/lb.)
$PAC3_t$	Three-year average of PAC_t based on periods t-2, t-1, t	(¢/lb.)
PFE_t	Price received by growers for fresh apples in East in year t	(¢/lb.)
PPE_t	Price received by growers for processed apples in East in year t	(¢/lb.)
PAE_t	Average price received by growers in East in year t	(¢/lb.)
$PAE3_t$	Three-year average of PAE_t based on periods t-2, t-1, t	(¢/lb.)
PF_t	Price received by growers for fresh apples in year t	(¢/lb.)
PP_t	Price received by growers for processed apples in year t	(¢/lb.)
IPP_t	Index of prices paid by farmers in year t	(1977=100)
$IPP3_t$	Three-year moving average (t,…,t-2) of IPP_t	
T	Time index, incremented by 1 each year (1971=1)	
D81	Dummy variable (0 before 1981, 0 otherwise)	
D86	Dummy variable (0 before 1986, 1 otherwise)	
D867	Dummy variable (1 in 1986-87, 0 otherwise)	
D879	Dummy variable (1 in 1987-89, 0 otherwise)	
D967	Dummy variable (1 in 1996-97, 0 otherwise)	
NIF_t	Net imports of fresh apples in year t	(mill. lb.)
NIP_t	Net imports of processing apples (fresh fruit equivalent) in year t	(mill. lb.)
PIF_t	Unit value of fresh net imports in year t	(¢/lb.)
PIP_t	Unit value of juice net imports (fresh fruit equivalent) in year t	(¢/lb.)
POP_t	U.S. Population in year t	(mill.)
QUF_t	Per-capita utilization of fresh apples with net imports in year t	(lb./capita/year)
QUP_t	Per-capita utilization of processed apples with net imports in year t	(lb./capita/year)
$QUFB_t$	Per-capita consumption of fresh bananas in year t	(lb./capita/year)
$QUFO_t$	Per-capita consumption of fresh oranges in year t	(lb./capita/year)
$QUCPP_t$	Per-capita consumption of canned peaches in year t	(lb./capita/year)
$QUCEP_t$	Per-capita consumption of canned pears in year t	(lb./capita/year)
$QUJO_t$	Per-capita consumption of orange juice in year t	(lb./capita/year)
$PCEDC_t$	Private consumption expenditure per person on food in year t	($)

(all prices, including IPP_t, are deflated by the GDP deflator, 1992=100)

Table 4. Partial Elasticities (calculated at means)[a]

		Short Run (Year 1)	Long Run (Year 5)
Northwest			
Fresh Production	$\in_{QPFNW,PF}$	0.313	0.622
	$\in_{QPFNW,PP}$	-0.063	-0.025
Processed Production	$\in_{QPPNW,PF}$	0.504	1.139
	$\in_{QPPNW,PP}$	0.095	0.261
Southwest			
Fresh Production	$\in_{QPFSW,PF}$	0.359*	0.518*
	$\in_{QPFSW,PP}$	-0.237*	-0.157
Processed Production	$\in_{QPPSW,PF}$	0.110	0.259
	$\in_{QPPSW,PP}$	0.197*	0.494*
Central			
Fresh Production	$\in_{QPFC,PF}$	0.873*	1.018*
	$\in_{QPFC,PP}$	-0.288*	-0.281*
Processed Production	$\in_{QPPC,PF}$	0.033*	0.197*
	$\in_{QPPC,PP}$	0.004*	0.054*
East			
Fresh Production	$\in_{QPFE,PF}$	0.639*	0.717*
	$\in_{QPFE,PP}$	-0.162*	-0.159*
Processed Production	$\in_{QPPE,PF}$	0.026*	0.225*
	$\in_{QPPE,PP}$	0.008*	0.071*
Consumption			
	$\in_{QPF,PF}$	-0.374	-0.374
	$\in_{QPP,PP}$	-0.701	-0.701
	$\in_{QPT,PA}$	-0.554	-0.554
	$\in_{QPF,PCEDC}$	1.195	1.195
	$\in_{QPP,PCEDC}$	2.591	2.591
	$\in_{QPT,PCEDC}$	1.961	1.961
Import			
	$\in_{NIF,PF}$	-0.609	-0.609
	$\in_{NIP,PP}$	-0.791	-0.791
	$\in_{NIF,QPF}$	-3.276	-3.276
	$\in_{NIP,QPP}$	-3.193	-3.193

[a] The asterisk marks significance at the 10% level.

Table 5. Total Supply Response Elasticities (calculated at means)[a]

		Short Run (Year 1)	Long Run (Year 5)
Northwest			
Fresh Production	$E_{QPFNW,PF}$	0.306	0.623
	$E_{QPFNW,PP}$	-0.059	-0.006
Processed Production	$E_{QPPNW,PF}$	-0.220	0.237*
	$E_{QPPNW,PP}$	0.229*	0.272*
Southwest			
Fresh Production	$E_{QPFSW,PF}$	0.346*	0.540*
	$E_{QPFSW,PP}$	-0.225*	-0.065
Processed Production	$E_{QPPSW,PF}$	-0.055*	0.215*
	$E_{QPPSW,PP}$	0.279*	0.452*
Central			
Fresh Production	$E_{QPFC,PF}$	0.868*	0.981*
	$E_{QPFC,PP}$	-0.288*	-0.269*
Processed Production	$E_{QPPC,PF}$	-0.831	-0.668
	$E_{QPPC,PP}$	0.291	0.295
East			
Fresh Production	$E_{QPFE,PF}$	0.638*	0.708*
	$E_{QPFE,PP}$	-0.162*	-0.157*
Processed Production	$E_{QPPE,PF}$	-0.467	-0.288
	$E_{QPPE,PP}$	0.133	0.180

[a] The asterisks marks significance at the 10% level.