Changes in Transportation Costs and Interregional Competition in the U.S. Apple Industry

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An interregional competition model of the U.S. apple industry is constructed. This model includes the consumer products of fresh apples, applesauce and apple juice. The validation of the model showed that it did a good job of estimating consumer's quantity demanded and prices and a reasonable job of estimating utilization. This model was used to study the effects of transportation cost changes on the industry in the short- and intermediate run. The total production and consumption levels changed by moderate amounts with changing transport costs while the utilization of a region's crop was quite sensitive to such changes.

The price of transportation is considered to be an important determinant of the relative profitability of agricultural production in different regions of the United States. Over time, transportation prices have changed, both because of changes in the underlying economics of the service provided, and because of changes in transportation regulations. These price changes can potentially have substantial effects on the spatial economics of a commodity.

Apples, like many agricultural commodities, are consumed in several forms. The primary forms, fresh apples, applesauce, and apple juice, have different characteristics in transportability and storability. This means that the optimal production and usage pattern for the U.S. apple industry depends on storage costs, processing costs, and transportation costs for each product form. Because of the different characteristics of the product forms, the most efficient mode of transportation for one form may be different than for another form.

This varying suitability of a particular mode for a particular product form creates a unique interaction between transportation prices and interregional competition for apples. Changes in either costs or regulations of one mode relative to another can affect not only the profitability of raising apples in a particular region, but also the profitability of a particular product form relative to its alternatives. Considerable regional specialization is present in specific apple products. The northwestern states of Washington, Oregon and Idaho are the major producers of apples for the fresh market. These states are only minor producers of applesauce. In contrast, applesauce is mainly an eastern product, and is the major apple use in several northeastern states. As a result, a change in transportation costs for applesauce would probably affect the northeast more than the northwest, while a change in fresh apple transport costs would affect the northwest more.

This study will develop a spatial equilibrium model of the U.S. apple industry which includes dimensions of price, space, and product form. The model will then be used to examine the relationship between changes in transportation rates and the location of apple production for both fresh and processed apple products. Then a variety of changes in transportation rates will be examined for their short and longer run impacts on the apple economy.

The Model

The economics of space and alternative product forms are presented in Bressler and King.

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The conceptual models Bressler and King use are operationalized in Takayama and Judge through the use of quadratic programming. The requirements for empirically solving such models are information about regional supplies, regional demands, processing and other marketing costs, and transportation costs. Although this appears to be a straightforward process, in fact none of this information is readily available. However, estimates of the required parameters based upon those data which are available can be made.

In this study the country is divided into nine regions, six of which have substantial production. The production regions are New York–New England, Appalachia, Great Lakes, Pacific Northwest, the Mountain States, and California. The remaining regions, which produce only small apple crops are the Southeast, the South Central and the Upper Midwest.

Three product forms are included, fresh, canned (primarily sauce), and juice. The other uses of apples, such as frozen or dried, are a much smaller part of the crop and are not considered.

Regional Supply

There is good information available about the quantity of apples produced by states and farm prices in these states. This provides an accurate picture of a single point in time. However, since apples are perennials, with planting decisions preceding the harvest by several years, the dynamics of supply are quite different than for annuals, and in general, poorly understood. French and Matthews have developed strong empirical ties to the theoretical models. However, their study of asparagus depends on data much better than that available for apples. Although studies of apple supply for a single state have been conducted, they have required either very long time series (Dunn and Beilock; Hayward, Criner and Skinner) or substantial interpolation to generate missing values (Price and Baritelle; Hayward, Criner and Skinner). For purposes of this study, two supply elasticities are used, an elasticity of zero for the short run, and an elasticity of 0.25 for the longer run. The estimates of Dunn and Beilock suggest that an elasticity of 0.25 represents a period of about 12 years, the long run for most crops but the medium run for apples. An even longer run elasticity could be tried but so many other factors would change over such a long period that little would be learned.

Many varieties of apples are grown commercially. All varieties are not equally well suited for a particular use. For the purposes of this study, the varieties are divided into three broad usage groups, fresh market, processing market, and dual purpose, with the primary usage as the group name suggests. All varieties are suitable for juice production.

Small, odd sized or bruised apples can be used for apple juice. As a result, some portion of both sauce and fresh market apples are used for juice. A cull rate of 15 percent for fresh and 10 percent for sauce apples is believed to represent industry averages and is used.

Dividing production for 1980–84 into usage groups, an average quantity of each usage group is found for each region. Average real farm prices are also available over this period. These average price and quantity figures are used to generate the supply functions with own-price elasticities of 0.0 and 0.25 which will be used for the simulations. Quantity data for 1981 is also used for validation purposes. All quantities are adjusted for reporting discrepancies and usage for other product forms.

Regional Demand

There is no regional consumption data available for most food products, including apple products. The best alternative is to estimate national demand relationships and assume that variations in per capita consumption between regions are because of differences in regional prices and incomes, but not differences in tastes and preferences. Thus the estimation of national per capita demand functions is required. To do this, annual time series data for the period 1960–83 are used. The models estimated, using ordinary least squares estimation, are found in Table 1.

The demand for fresh apples is estimated in price dependent form, while the demand for sauce and juice are estimated in quantity dependent form. The use of price dependent demand equations for perishable foods is advocated by Heien, and applied to fresh apples by Hayward, Criner, and Skinner. The specification suggests that price must adjust to clear the markets of the pre-determined quantity supplied rather than allow the quantity supplied to adjust via changes in inventory levels as is possible with storable products.

Table 1. Estimated Per Capita U.S. Apple Demand Relationships, 1960–83[1]

$$\ln P_F = -3.336 - \underset{(-1.51)}{0.267 \ln Q_F} + \underset{(2.82)}{0.319 \ln P_{FF}} + \underset{(4.69)}{0.329 \ln Y} \qquad R^2 = 0.69 \qquad d.w. = 1.65$$

$$\ln Q_S = 1.209 - \underset{(-0.83)}{0.161 \ln P_S} - \underset{(-2.08)}{0.601 \ln P_{CF}} + \underset{(3.50)}{0.481 \ln P_{FF}} - \underset{(-3.70)}{0.065\, T} \qquad R^2 = 0.67 \qquad d.w. = 1.82$$

$$\ln Q_J = -8.091 - \underset{(-1.63)}{0.367 \ln P_J} + \underset{(1.54)}{0.982 \ln Y} + \underset{(4.82)}{0.770 \ln Q_{JT-1}} \qquad R^2 = 0.96 \qquad d.w. = 1.71$$

Q_F = per capita fresh quantity consumed (lbs.)[2]
Q_S = per capita sauce quantity consumed (lbs.)[2]
Q_J = per capita juice quantity consumed (lbs.)[2]
P_F = real fresh price per pound ($)[2]
P_S = real sauce price per pound ($)[3]
P_J = real juice price per pound ($)[3]
P_{FF} = real fresh fruit price index (excluding apples)[3]
P_{CF} = real canned fruit price index (excluding applesauce)[3]
Y = real per capita personal income ($100)[4]
T = time (1–24)

[1] Values in parentheses are t statistics.
[2] Source: U.S.D.A. *Food Consumption, Prices and Expenditures.*
[3] Source: Calculated using information from U.S.D.A., *Food Consumption, Prices and Expenditures,* and B.L.S. *Producer Prices Indexes.*
[4] Source: *Economic Report of the President.*

The equations are estimated in log-log form because the implied assumption of constant elasticities is more consistent with a market such as apple juice than is the assumption of constant slopes, and therefore widely changing elasticities, which a linear specification requires. This is generally true for any long time series, especially when a wide range of prices and quantities have occurred.

The estimated demand equations show fresh apples to have an elastic own-price elasticity of demand, applesauce an inelastic own-price elasticity of demand, and apple juice an inelastic demand in the short run and elastic demand in the long run. The distinction between long and short run for apple juice is the result of the lagged dependent variable as a regressor in this equation. As such, it represents a habit component to demand, with a coefficient near zero representing little habit and a coefficient near one representing substantial habit. Fresh apple and applesauce demand exhibited no observable habit effects.

The own price and quantity coefficients showed uniformly poor statistical strength. This is probably because price data inadequately reflected prices paid. The lack of good consumer price data is a problem in all demand estimation, especially for narrowly defined products. Despite their lack of significance, the estimated own-price elasticities are consistent with other research.

An index of prices of other fresh fruits and income were also determinants of fresh apple demand. Applesauce demand was found to be positively affected by the price of fresh fruits but negatively affected by the price of other canned fruits. This apparently reflects a decision to consume canned fruits as a group based on fresh fruit prices and canned fruit prices, where canned fruits are viewed as complements. Time, a proxy for tastes and preferences, showed a negative effect on applesauce demand, a reflection of the decrease in canned fruit demand over time despite lower real prices. Income was not included in this equation because of its collinearity with time. The coefficient reflects a decrease in consumption of about 4 percent per year.

Apple juice demand, which has been growing steadily, has a short run price elasticity of demand of −0.320 and a large estimated income elasticity. This income elasticity is probably the sum of the income effect and a change in tastes and preferences towards apple juice consumption in recent years. An index of other fruit juices (primarily orange juice) had no observable effect on apple juice demand.

In all instances, the goal was to specify demand equations which contained the arguments implied by demand theory. Since demand theory does not specify exactly which other prices might have substantial impact, flexibility about model specification was maintained.

The spatial equilibrium model requires linear regional total demand functions with price as a function of quantity. These were generated from the national per capita demand functions using a four step process. First a preliminary regional quantity consumed was determined by taking the average national per capita consumption for the period 1980–84 and multiplying it by regional population. This figure was then adjusted for regional income differences using the estimated income elasticities. Regional price levels were found by adjusting real national prices for 1980–84 transportation costs, assuming that the Great Lakes region faces average price levels. The estimated own price elasticity, combined with a price and quantity combination for each region, can then be used to derive the linear demand function with that elasticity at that price and quantity.

All prices and quantities are expressed in fresh equivalents to allow a simpler specification of the programming model. The supply and demand relations are expressed in price dependent form to allow the model to be solved in quantity space. This specification is more flexible with multiple product forms and is similar to linear programming transportation models.

Transportation Rates

Transportation rates for shipments of fresh apples and processed apple products are required for the quadratic programming model. Truck rates for 1981 are from the *Fruit and Vegetable Truck Rate Report*. The average of the rates for the first week of each month are used. Although these rates are for fresh fruit, it is assumed that the processed fruit receives the same truck rate, adjusted for differences in load size. Rail rates are from sample waybills.

Traditionally fresh fruit and short-haul processed fruit moves by truck, and long-haul processed fruit moves by rail. Improvements in piggyback and container on flatcar service have increased the movements of fresh fruit by rail. Piggyback rates are generated by adjusting the truck rates for the potential cost savings estimated by Beilock.

Processing and Other Marketing Costs

The cost of marketing services other than transportation are estimated by adjusting the spreads between retail and farm prices in large producing and consuming regions for transportation costs. These figures are comparable to those available only for some months in the *Fruit Situation and Outlook*. These figures are also adjusted for regional differences in on-farm marketing activities and varietal premiums.

Validation

Validating computer models is an intractable methodological problem. Those situations where a model is most useful are often the situations where the underlying data are least available. Accordingly where the information value of a "good" model is potentially the greatest, it may be the most difficult to determine if a model is "good."

Naylor and Finger describe a three stage validation procedure which combines rationalism, empiricism, and positive economics. What this means in practice is the model is originally constructed using a combination of economic theory and practical knowledge of the actual situation in a manner which includes the important characteristics of the situation in a reasonable manner. Then statistical tests are used, where possible, to test some of the underlying assumptions. In this model, only the econometrically estimated demand equations have adequate data for empirical validation. The final stage is to test the predictive ability of the model for the system under study. This may involve historical simulation or forecasts. In this instance, historical validation is used with 1981 as the test year. That information which is available for 1981 is compared to the corresponding information generated by the model. This method assumes that if the information for which comparable data are available are satisfactory, then those estimates for which comparable data are not available are also satisfactory. As a further test, a historical simulation is conducted for the average production for 1980–84. Changes in the regulation of rail rates have made rail data for years since 1981 unobtainable, so 1981 rate information is also used for this simulation.

Table 2. Utilization Predictions for 1981 and 1980–84 Average Compared to Actual Quantities with Production Fixed (100 mil. lbs.)

Supply Region/ Product Form	Actual 1981	Estimated 1981	Actual 1980–84	Estimated 1980–84
New York–New England				
Fresh	6.330	6.877	7.150	7.529
Sauce	2.120	1.885	2.750	1.895
Juice	2.850	2.537	3.100	3.576
Appalachia				
Fresh	6.488	5.443	6.300	6.705
Sauce	4.282	5.939	5.300	5.971
Juice	3.975	3.363	4.000	2.924
Great Lakes				
Fresh	6.554	5.029	6.900	6.394
Sauce	1.351	1.555	1.600	1.430
Juice	2.610	3.932	3.400	4.076
Northwest				
Fresh	22.740	23.629	23.700	24.125
Sauce	1.071	0.870	1.050	1.006
Juice	4.959	4.266	4.750	4.370
Mountain States				
Fresh	0.985	0.959	0.850	0.850
Juice	0.465	0.490	0.350	0.350
California				
Fresh	1.440	1.224	1.550	1.027
Sauce	1.200	1.221	1.050	1.227
Juice	3.140	3.335	2.350	2.596

Actual data are from U.S.D.A., *Non Citrus Fruits and Nuts, Annual Summary, Production, Use, and Value.*

A comparison of actual and predicted regional utilization for each product is shown in Table 2. The model predicts utilization patterns which are similar to the actual utilization. Generally the model is robust in allocation between geographically distant regions and quite sensitive to minor changes in transportation and marketing costs between geographically close regions.

The farm and retail price predictions are close to the actual values. The error in the price predictions is small relative to actual interyear variation in apple prices.

The distribution patterns in general compare well with the *Fruit and Vegetable Unloads* patterns. One flow not predicted is the movement of northwestern fresh apples into New York City. This is apparently the result of inadequate varietal or seasonal distinction. The lack of varietal distinction is also observed in the failure of the model to predict the movements of Northeastern apples into the Midwest. These movements are probably unable to be modeled using practical methods, since varietal retail demand functions would require data which are not presently available.

The model captures the important regional production patterns of the different product forms, with applesauce mainly an eastern product, especially in Appalachia, and the Northwest primarily a fresh market area. It also reflects the residual nature of juice production in all areas.

Overall the model resembled the actual markets for the periods examined. Those problems that do occur are not easily remedied, and must therefore be recalled when examining these portions of the model in the simulations.

Simulations

Three basic situations are examined. Within each of these situations, two variations are considered, representing different time periods. They represent periods of 1 and 12 years and assume price elasticities of supply of 0.0 and 0.25, respectively.

The first situation replaces cross country rail rates with Trailer on Flatcar (TOFC) rates. Trailer on Flatcar shipments (or piggyback) are a growing percentage of all rail movements. These shipments move faster than rail

Table 3. Utilization Predictions with TOFC Availability in One and Twelve Years Compared to Estimated 1980–84 Average Quantities (100 mil. lbs.)

Supply Region/ Product Form	Estimated 1980–84	One Year $\eta = 0.0$	Twelve Years $\eta = 0.25$
New York–New England			
Fresh	7.529	7.730	7.780
Sauce	1.895	1.898	1.899
Juice	3.576	3.372	3.236
Total	13.000	13.000	12.915
Appalachia			
Fresh	6.705	6.104	6.142
Sauce	5.971	5.980	5.983
Juice	2.924	3.516	3.345
Total	15.600	15.600	15.470
Great Lakes			
Fresh	6.394	7.318	7.103
Sauce	1.430	2.041	2.042
Juice	4.076	2.540	2.647
Total	11.900	11.899	11.792
Northwest			
Fresh	24.125	23.548	23.941
Sauce	1.006	1.616	1.617
Juice	4.370	4.334	4.404
Total	29.501	29.498	29.962
Mountain States			
Fresh	0.850	0.850	0.865
Juice	0.350	0.350	0.356
Total	1.200	1.200	1.221
California			
Fresh	1.027	1.027	1.021
Sauce	1.227	0	0
Juice	2.596	3.823	3.965
Total	4.850	4.850	4.986

and when drayages (the over the road portion of a TOFC movement) are short, TOFC is considerably cheaper than truck movements. It is anticipated that as TOFC service becomes more widely available, cross-country truck movements of fruits and vegetables will decrease substantially.

The results of these simulations are given in Table 3. With TOFC widely available, pressure for some production shifts would occur over time. In particular (1) the New York–New England area would decrease total production somewhat, continuing to concentrate on fresh markets. (2) The Appalachian region would decrease production to a greater extent, decreasing the production of fresh apples while maintaining sauce and juice production. (3) The Great Lakes region would cut its juice production sharply and become largely a fresh market supplier. (4) The Northwest region would increase sauce production and decrease fresh production, with a total production increase and (5) the California region would move out of sauce production and into juice, with some increase in total production.

The impact of greater TOFC availability would be greatest in the Appalachian region, which is vulnerable in each of the products they produce, especially if national applesauce demand continues to fall. Domestic juice production would largely move west, in the short run at the expense of some fresh usage. In general, wider availability of piggyback affects the economics of alternative product form, with smaller effects on total production.

Situations two and three are complements of one another. In situation two the over the road portion of truck rates decreases by 20 percent, in situation three it increases by 20 percent. These situations represent a change in the economics of trucking versus rail be-

Table 4. Utilization Predictions with Different Truck Rates in One and Twelve Years (100 mil. lbs.)

Supply Region/ Product Form	Lower Rates		Higher Rates	
	One Year $\eta = 0.0$	Twelve Years $\eta = 0.25$	One Year $\eta = 0.0$	Twelve Years $\eta = 0.25$
New York–New England				
Fresh	7.694	7.753	7.758	7.800
Sauce	0.255	0.418	2.483	2.664
Juice	5.050	4.758	2.759	2.439
Total	12.999	12.929	13.000	12.903
Appalachia				
Fresh	6.062	6.108	6.155	6.187
Sauce	7.621	7.462	5.398	5.219
Juice	1.917	1.907	4.047	4.049
Total	15.600	15.477	15.600	15.455
Great Lakes				
Fresh	7.406	7.208	7.225	6.988
Sauce	2.041	2.041	2.041	2.043
Juice	2.453	2.551	2.633	2.752
Total	11.900	11.800	11.899	11.783
Northwest				
Fresh	23.548	23.960	23.547	23.923
Sauce	1.616	1.617	1.617	1.617
Juice	4.336	4.407	4.335	4.401
Total	29.500	29.984	29.499	29.941
Mountain States				
Fresh	0.850	0.859	0.850	0.870
Juice	0.350	0.354	0.350	0.358
Total	1.200	1.213	1.200	1.228
California				
Fresh	1.027	1.022	1.027	1.022
Sauce	0	0	0	0
Juice	3.823	3.969	3.823	3.961
Total	4.850	4.991	4.850	4.983

cause of changes in highway taxes or gasoline taxes. It does not represent the impact of a change as far-reaching as general energy price inflation. Energy price inflation affects much more than just transportation prices, and has different impacts than do rate changes (Dunn). Both of these situations also assume TOFC availability for cross-country rail movements.

Like widely available TOFC, changes in truck rates also have more impact on utilization than on production. As seen in Table 4, they would affect New York–New England juice and sauce production, trading off somewhat with Appalachian sauce and juice usage. The applesauce production in the Great Lakes region would grow at the expense of juice. Western production is not affected greatly by changes in truck rates in the presence of TOFC, since it is a surplus region that hauls mostly by rail to its distant customers. Truck rates primarily affect the cost of serving the southeast from the northeast, with some intraregional effect from the lower marketing costs.

In general, the simulations showed that regional apple usage is quite sensitive to transportation rates. In the long run, when production levels can react, regional production shifts can occur, but these tend to be less important than the usage shifts. Although price levels are also affected, the elastic demand for fresh apples provides considerable price stability.

Conclusions

This study shows how changes in transportation costs can affect the competitive positions of different regions. Lower transportation costs can represent both a threat and an opportunity. For example, northeastern apple producers face lower prices for their fresh apples when transportation prices fall since the exporting northwestern region can serve distant markets more competitively. However, the northeast exports applesauce and lower transport costs aid their competitive position in applesauce markets. This suggests that changing transportation costs will have differential impacts even within the northeast. The impact depends on what markets are being served. As with most food products, the cost of transporting apple products is a small portion of the retail price, but is considerably larger relative to the farm price. When this cost importance is combined with the inelasticity of supply, the profitability of apple production is quite sensitive to changes in transportation costs.

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