Effect of Imports on US Prices for Fresh Apples

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Abstract: This paper presents new econometric evidence concerning the variation of fresh apple prices in the US market as a function of fluctuations in supplies from seven major US and non-US supply areas. The Rotterdam inverse demand system recently developed by Barten and Bettendorf is used in the analysis. The results show that the impact on prices stemming from a change in overall quantities of fresh apples varies widely across supply regions. The price of Washington apples would suffer a marked drop with a rise in total quantity. The analysis also suggests that Chile's entrance into the US apple market has had a negligible impact on prices.

Introduction

Over the last several years, apple growers in the USA have encountered an adverse economic environment stemming from lower prices for their products (Sparks, 1989). A major determinant of lower farm prices has been a sharp increase in US production resulting from heavy tree plantings in the late 1970s and early 1980s. In addition, apple production in Chile, New Zealand, South Africa, and Canada and imports from these countries into the US market have increased substantially in the last two decades.[2] Another major factor contributing to lower apple prices has been a relatively constant consumption level.

The increase in apple production observed in recent years in several major supplying nations, including New Zealand, South Africa, and Chile, is expected to continue. This production growth is likely to be particularly strong in less-developed countries as they struggle to generate badly needed foreign exchange (USDA, 1989 and 1990). For example, apple production in Chile, a relatively new player on world apple markets, is expected to double in the next decade (O'Rourke, 1987). These non-US suppliers will be looking beyond their national borders for markets in which to sell their products, including in the USA.

Apple production makes a significant contribution to farm income in various regions of the USA and in several other countries. Nevertheless, there is little recent economic analysis designed to understand the interaction between apple production and price levels as supply from competing regions changes. The purpose of this paper is to present new econometric evidence concerning the variation of fresh apple prices in the US market as a function of fluctuations in supplies from major US and non-US supply areas. The recently developed Rotterdam inverse demand system (Barten and Bettendorf, 1989) is used in the analysis.

Methodology

Econometric estimates of relationships between prices and quantities of apples using a variety of specifications have been reported in the literature.[3] Studies using an inverse demand specification include those of Carman and Kenyon (1969), Edman (1972), and Baritelle and Price (1974). These studies, however, have focused on local or regional US markets and have often been formulated on an *ad hoc* basis without much attention given to *a priori* restrictions stemming from demand theory.

The model used in this paper explicitly accounts for restrictions derived from demand theory. It starts by assuming that the total commodity bundle is weakly separable, which makes it possible to treat the commodity group of interest, fresh apples in this case, as being independent of all other groups (Phlips, 1974). Under weak separability, the (direct) market demand system for fresh apples can be written as:

(1) $D_i = f(P, E)$

where D_i is the demand function for fresh apples produced in the ith region, P is a vector of apple prices, $E = P'Q$ is total expenditure on apples, and Q is a vector of apple quantities. In this formulation, fresh apples are differentiated by the region where they are produced, and they are not considered to be perfect substitutes. The inverse demand system corresponding to Equation (1) is given by:

(2) $P_i = f^{-1}(Q, E)$

Although the direct demand system is equivalent to the inverse system from a theoretical point of view, these two approaches are not equivalent econometrically. The choice of one approach over the other in empirical work depends on which variable, price or quantity, is considered to be exogenous. Waugh (1966, p. 81) suggested that in agricultural markets "... changes in prices are generally determined by changes in quantities and changes in income—not the other way around." More recently, Salvas-Bronsard *et al.* (1977, p. 310) have argued that a price-dependent demand system is appropriate when "... supply is quite inelastic, or [if] ..., within a year, quantities are determined independently of prices."

Apples are perennials. The size of the apple crop in any one year, depends, to a large extent, on planting decisions made several years earlier and is not related to current market conditions. Based on these arguments, the inverse demand framework is chosen in this study to model the price formation of fresh apples in the wholesale market.

The specific model used is the price-dependent Rotterdam demand system (Barten and Bettendorf, 1989), which is the inverse equivalent of the regular Rotterdam system developed by Theil (1975 and 1976). The equation to be estimated is:

(3) $\bar{s}_{it}\Delta\, ln\, r_{it} = \beta_i\Delta\, ln\, Q_t + \Sigma_j\beta_{ij}\Delta\, ln\, q_{jt} + \varepsilon_{it}$ $\quad (i, j = 1, 2, ..., 7; t = 1969, ..., 1986)$

where:

(4) $\bar{s}_{it} = 0.5(S_{it}+s_{i,\ t-1})$

(5) $r_{it} = P_{it}/S_t$

(6) $Q_t = \Sigma_j\bar{s}_{jt}\Delta\, ln\, q_{jt}$

and $s_{i,\ t}$ is the market share of fresh apples from region i sold in year t; P_i is the average wholesale price of apples from region i; S_t is the total value of fresh apples from all regions sold in the US market in year t; q_{jt} is the quantity of fresh apples sold in the US market from supply region j in year t; β_i and β_{ij} are parameters to be estimated; and ε_{it} is an error term that is assumed to be normally distributed with mean zero and constant variance. The inverse demand system consists of seven equations, one from each producing region, as discussed below.

Restrictions resulting from demand theory require that $\Sigma_i\beta_i = -1$ and $\Sigma_i\beta_{ij} = 0$, which corresponds to the adding-up property. The homogeneity property is satisfied when $\Sigma_j\beta_{ij} = 0$, and symmetry requires that $\beta_{ij} = \beta_{ji}$ (i.e., the estimated coefficients on the quantity parameters between the ith and jth supply regions are symmetric). The system is estimated using the iterative least squares option of the TSP econometric package.

Once the system of Equations (3) is estimated, it is possible to calculate the scale effect, which gives the change in the ith price (P_i) in response to a proportionate change in total quantity (Q). As shown by Barten and Bettendorf (1989), the scale elasticity (SE) can be computed from Equation (3) as:

(7) $$SE_{iQ} = \frac{\partial\ \ln\ r_i}{\partial\ \ln\ Q} = \frac{\partial\ \ln\ s_{it}}{\partial\ \ln\ Q} - 1 = \frac{\beta_i}{s_i}$$

A second relationship of interest obtained from an inverse demand system is the Antonelli substitution (AS) or quantity effect, which is equivalent to the substitution effect for a direct demand formulation. The AS effect is defined as the change in the normalized price of the ith good with respect to a marginal change in the consumption of the jth good, holding utility constant (Anderson, 1980). The Antonelli substitution effect between the *i*th and the *j*th good, calculated from Equation (3), is equal to the coefficient β_{ij}, and the Antonelli substitution elasticity is β_{ij}/s_i. Demand theory requires that the own Antonelli substitution effects β_{ii} be negative, while there is no *a priori* expectation on the sign of the cross effects β_{ij} (Anderson, 1980). To implement the model, the world is divided into seven apple-producing regions: Washington State; North-Central and Northeastern USA (NC–NE), including Michigan, New York, Ohio, Pennsylvania, Vermont, Massachusetts, Maine, Connecticut, and New Hampshire; rest of the USA; Canada; New Zealand; South Africa; and rest of the world. Annual price and quantity data for the 1969–86 period were obtained from USDA and UN sources.

Table 1 presents the prices, quantities, values, and value shares of apples in the USA from each of the seven supply regions for 1969 and 1986, and for Chile for 1975 and 1986. As can be seen from the data, the quantities and values of imported apples from Canada, Chile, New Zealand, South Africa, and the rest of the world increased substantially in this time period. Washington has experienced major gains as a supplier to the US market, in terms of both quantity and value share, while other regions of the USA have suffered considerable losses. The share of non-US apples, excluding Canada, has increased markedly over the past two decades but still plays a relatively minor role in the US fresh market. Chile has shown a very impressive growth, increasing from 600 t in 1975 to over 31,000 t in 1986, which, in the latter year, was over two-thirds of US imports from the rest of the world.

Table 1—Prices, Quantities, and Values of Fresh Apples in the USA from Major Suppliers, 1969–86

Supply Region	Year	Price ($/t)	Quantity (t)	Value ($)	Value Shares (%)
Washington	1969	77.0	552,476	42,385,933	13.50
	1986	410.0	1,106,766	453,840,341	32.20
NC–NE	1969	163.0	498,770	81,409,239	25.80
	1986	457.0	452,413	206,906,561	14.80
Rest of the USA	1969	154.0	1,179,839	181,553,625	57.60
	1986	419.0	1,572,242	658,580,729	46.80
Canada	1969	211.0	36,738	7,761,000	2.50
	1986	409.0	44,565	18,213,000	1.30
New Zealand	1969	323.0	2221	717,000	0.20
	1986	1026.0	26,917	27,605,000	1.90
South Africa	1969	446.0	1735	774,000	0.30
	1986	785.0	14,482	11,371,000	0.80
Rest of the world	1969	222.0	1,842	409,000	0.10
	1986	683.0	45,667	31,207,000	2.20
Chile*	1975	275.0	600	165,000	—
	1986	554.0	31,040	17,202,000	—

*Chile is included as part of the rest of the world.

Results

The parameter estimates for the seven-equation system are presented in Table 2. To facilitate the reading of the table, all estimated parameters and their standard errors are multiplied by 100. Given that all quantity effects (β_{ij}) are symmetric, the top portion of the parameter matrix is omitted. A total of 35 parameters are estimated, of which 10 are statistically significant at the 0.01 level, three at the 0.05 level, and two at the 0.10 level. As already mentioned, economic theory dictates that the diagonal elements of the Antonelli substitution matrix should be negative. This condition holds for all seven of the diagonal elements of the matrix shown in Table 2.

The Antonelli substitution elasticities along with their approximate standard errors are reported in Table 3. The cross-substitution elasticities reveal that Washington apples, the largest single-state source of apples in the USA, have a highly significant complementary relationship with apples from the rest of the USA. There is little relationship between the price of Washington apples and the quantities supplied by individual regions in the US market. The NC–NE region has a highly significant and fairly large complementary relationship with apples from the rest of the USA. It has a complementary relationship with Canadian and New Zealand apples, although these elasticities are quite small. Washington and New Zealand apples are complements to apples from the rest of the USA.

In contrast, apples from Canada and New Zealand are more evenly divided between substitutes and complements with respect to other suppliers to the US market. Canadian apples have a complementary relationship with those from NC–NE and South Africa, and are substitutes for New Zealand apples. NC–NE and rest-of-the-world apples are weak complements.

Of the seven scale elasticities shown in Table 3, four are statistically significant at the 5-percent level or higher. Of these four, two are negative, Washington and rest of the USA, and two are positive, New Zealand and South Africa. The negative scale elasticities suggest that a 1-percent increase in overall quantity would lead to a 2.2-percent and 0.8-percent drop in the prices of apples supplied by Washington and rest of the USA, respectively. In contrast, a similar rise in quantity would yield a gain in price of 2.0 percent for New Zealand and 1.6 percent for South African apples, both Southern Hemisphere producers.

As noted earlier, apple production in Chile has grown very rapidly, from 125,300 t in 1975 to 515,000 t in 1986. Most of this additional apple production has been for export to various non-Chilean markets, since Chilean consumption reached only 141,000 t in 1988/89. Chile began exporting apples to a significant degree in the mid- to late-1970s, and its role in international markets, which is still relatively small, is expected to increase as recently planted trees come into bearing age. There is concern that increased imports of Chilean apples into the USA have depressed the prices received by competing suppliers.

To assess the impact of imports from Chile on US fresh apple prices, the demand system was re-estimated.[4] A dummy variable with a value of zero in 1963–73 (when Chile was not a supplier) and a value of one in 1974–87 (when Chile was a supplier) was multiplied by the aggregate quantity variable. The significance of the coefficient on the dummy variable was used as a test of whether the entrance of Chile into the US apple market has had an impact on the scale elasticities of each of the major suppliers. For all suppliers, the coefficient on the dummy variable was statistically insignificant. This is not surprising if we consider that, despite the major rise in Chilean apple exports, this country remains a small participant in the US market.

Table 2—Parameter Estimates (×100) for an Inverse Rotterdam Demand Model for Fresh Apples, 1969–86

Supply Region	Quantity Effects							Scale Effects
	Washington	NC–NE	Rest of the USA	Canada	New Zealand	South Africa	Rest of the World	
Washington	−3.40							−54.06***
	(2.20)							(8.11)
NC–NE	−0.68**	−9.87***						−6.15
	(1.30)	(1.55)						(5.01)
Rest of the USA	3.97*	9.59***	−13.26***					−42.49***
	(1.87)	(2.03)	(3.28)					(5.98)
Canada	0.28	0.53**	−0.29	−0.34				−0.12
	(0.19)	(0.24)	(0.40)	(0.26)				(0.63)
New Zealand	−0.09	0.44**	0.08	−0.26**	−0.40***			1.89***
	(0.15)	(0.20)	(0.33)	(0.15)	(0.15)			(0.49)
South Africa	−0.06	−0.08	0.02	0.12**	0.05	−0.09***		0.65**
	(0.07)	(0.07)	(0.12)	(0.06)	(0.04)	(0.02)		(0.27)
Rest of the world	−0.04	0.06	−0.12	−0.05	0.16***	0.03***	−0.05*	0.28
	(0.11)	(0.15)	(0.24)	(0.05)	(0.04)	(0.01)	(0.03)	(0.41)

***Significant at the 1-percent level. **Significant at the 5-percent level. *Significant at the 10-percent level.

Table 3—Scale and Antonelli Substitution Elasticities Calculated from an Inverse Rotterdam Demand Model for Fresh Apples

Supply Region	Substitution Elasticities (calculated at sample means)							Scale Elasticities
	Washington	NC–NE	Rest of the USA	Canada	New Zealand	South Africa	Rest of the World	
Washington	–0.14	–0.03	0.16**	0.01	–0.00	–0.00	–0.00	–2.22***
	(0.09)	(0.05)	(0.07)	(0.01)	(0.01)	(0.00)	(0.01)	(0.33)
NC–NE	–0.03	–0.47**	0.45***	0.02**	0.02**	–0.00	0.00	–0.29
	(0.06)	(0.07)	(0.10)	(0.01)	(0.01)	(0.00)	(0.01)	(0.23)
Rest of the USA	0.08**	0.19***	–0.26***	–0.01	0.00	0.00	–0.00	–0.84***
	(0.04)	(0.04)	(0.06)	(0.01)	(0.01)	(0.00)	(0.01)	(0.11)
Canada	0.20	0.37**	–0.20	–0.23	–0.18*	0.08**	–0.04	–0.09
	(0.14)	(0.16)	(0.27)	(0.18)	(0.10)	(0.04)	(0.03)	(0.44)
New Zealand	–0.09	0.48**	0.09	–0.28*	–0.43***	0.06	0.18***	2.04***
	(0.17)	(0.22)	(0.36)	(0.16)	(0.16)	(0.05)	(0.04)	(0.53)
South Africa	–0.14	–0.19	0.04	0.30	0.13	–0.22***	0.08**	1.63**
	(0.19)	(0.19)	(0.30)	(0.14)	(0.11)	(0.05)	(0.03)	(0.67)
Rest of the world	–0.05	0.08	–0.14	–0.06	0.20	0.04**	–0.07	0.34
	(0.14)	(0.18)	(0.29)	(0.05)	(0.05)	(0.01)	(0.04)	(0.50)

Note: Approximate standard errors in parentheses. ***Significant at the 1-percent level. **Significant at the 5-percent level. *Significant at the 10-percent level.

Conclusions and Implications

While consumption of fresh apples in the USA has remained fairly constant, production has been increasing in both the USA and several other countries. This trend is expected to continue for the next several years. These conditions are placing downward pressure on the prices US farmers receive for their product, forcing adjustments in the industry.

In order to measure the effects of increasing quantities on prices of fresh apples from each of the major suppliers to the US market, an inverse Rotterdam model was constructed and estimated. The results indicate that the impact on US apple prices of increased supplies varies considerably by supply region. The price of apples from Washington state, the largest single supplier in the USA, is affected positively by increasing supplies from the rest of the USA. Changes in the quantity of apples from other individual supply regions have little effect on the price of Washington apples. Nonetheless, the scale elasticities indicate that the price of Washington apples, as well as that of the rest of the USA, is negatively affected by increases in total supplies to the US market. In contrast, empirical results indicate that the prices of apples from New Zealand and South Africa, both Southern Hemisphere suppliers, are augmented significantly by increased apple supplies in the US market. An analysis to account for Chile's entrance into the US apple market showed that, up to now, Chile has had a negligible impact on the price of apples sold in the USA.

Notes

[1]US Department of Agriculture and University of Connecticut, respectively.

[2]For political reasons, the USA has imposed a ban on imports from South Africa. Before the ban, South Africa was a relatively large non-US supplier of fresh apples to the US market. Hence, a lifting of the import restriction would probably enable South Africa to resume its role of relative prominence in the US market.

[3]For a review of several studies see Nuckton, 1978.

[4]The results are not shown due to space limitations.

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Discussion Opening—*Sibylle Scholz* (Winrock International)

The methodology used is well thought out with respect to the choice of an inverse demand system. Among agricultural goods, tree crops are probably the least influenced by short-term price fluctuations. The correct sign and significance of the estimated parameters partially confirm the appropriateness of the model.

However, the size of the parameters is in need of some explanation. Given an ever-increasing amount of substitutes for apples, one would expect the demand elasticity for the USA to be in the elastic range. The coefficients for Washington, NC–NE, and the rest of the USA are all greater than one in absolute terms, which means that demand is in the inelastic range since these coefficients are from the inverse demand function.

Given that the demand elasticities are in the inelastic range, it is correct to conclude that an increase in supply will lead to downward pressures on producers' revenues. However, it is not quite correct to use a fairly constant US consumption of fresh apples as an added condition on downward pressures of producer revenues. This latter point leads into an additional question about the unit of analysis.

Is the choice of apple produced related to final consumption? In other words, is an apple produced for fresh consumption a different apple from one produced for sale to Sara Lee to go into an apple pie? To what extent do processing industries absorb the increased supply of apples? What proportion of wholesale fresh apples is consumed as fresh apples? What proportion of total apples produced is consumed fresh?

Given the recent development in post-harvest technologies and an ever-increasing supply of prepared, premixed juices, jellies and chewables, microwaveables, individually wrapped deep-frozen "ready-to-pop" tarts, supply fluctuations, at least within the USA, might be absorbed in processing. This, coupled with a highly concentrated food processing industry, might explain why demand is in the inelastic range. I mean to imply that price-strategic behaviour by apple-processing industries might push demand into the inelastic range. This would imply that USA apple producers have more to fear from US industries than from non-US apple producers.

[Other discussion of this paper and the authors' reply appear on page 211.]