Forecasting Price Trends in the U.S. Avocado (*Persea americana Mill.*) Market

Edward A. Evans and Sikavas Nalampang

The United States is the world's leading importer and second-largest producer of avocados. U.S. per capita consumption increased from 0.69 kg in 1998 to 1.48 kg in 2007. The factors responsible include aggressive promotion of the health benefits, increased disposable income, and a rapidly growing Hispanic population. Such factors enabled the prices of avocados to remain fairly attractive over the period. However, with the recent downturn in the U.S. economy and prospects of further increases in supplies of avocados, there are concerns that prices could fall substantially. With the aid of multiple-regression analysis, this paper forecasts avocado prices up to the year 2012.

U.S. production of avocados occurs in three regions: California, Florida, and Hawaii. California is by far the largest producer, accounting for over 90 percent of production, on average, followed by Florida with about nine percent, and Hawaii with less than one percent. California grows mainly Hass avocados (characterized by purplish-black skin) in San Diego, Riverside, Ventura, and Santa Barbara Counties. Florida avocados have green skins and are grown mainly in Miami-Dade County.

The United States is the world's second-largest avocado producer but still lags far behind Mexico. In the 2006 cropping season, the United States accounted for about 7.4 percent of global avocado production, compared with Mexico which accounted for 34.2 percent (Table 1). As can be observed in Table 1, U.S. avocado production exhibits an erratic pattern, reflecting alternate high- and low-bearing years, which is characteristic of avocado production. In general, however, there has been an upward trend. From 173,000 tons produced in the 1996/97 season, production grew to 256,000 tons in the 2005/06 season, and then fell to 247,000 tons in the 2006/07 season (FAOSTAT n.d.).

Since the late 1980s, the United States has become a net importer of avocados. Moreover, in 2002 the United States overtook France to become the world's leading importer of avocados. Figure 1 shows the trend in U.S. imports of avocados from 1998 to 2007.

The main sources of U.S. imports of avocados are Mexico, Chile, the Dominican Republic, and New Zealand. Hass cultivars are imported from Mexico, Chile, and New Zealand and the green-skinned cultivars are imported from the Dominican Republic. Mexico and Chile, with shares of 62.9 percent and 32.1 percent, respectively, dominate the U.S. avocado-import market, accounting for 95 percent of the total imports in 2007. As illustrated in Figure 2, up until 2004, the main supplier of avocados to the United States was Chile, followed by Mexico. However, this situation was reversed in 2005, when Mexico more than tripled the amount of avocados it ships to the United States (from 39,000 tons in 2004 to 134,000 tons in 2005). This represents an increase of 95 tons (244 percent) over the previous year. In comparison, imports from Chile increased by 21 tons (22 percent) to 115 tons during the same period.

The main driving force behind the sharp increase in imports of avocados entering the United States is the elimination of trade restrictions on imports of avocado shipped from Mexico (USDA 2006). While Mexico is the world's largest producer of avocados, it was banned from the U.S. market for a long time for phytosanitary reasons. However, times have changed and the entire U.S. market was opened to avocado shipments from certified areas in Mexico in 2007.

As a consequence of opening the U.S. market to imports from Mexico, along with other factors discussed below, U.S. consumption of avocados has increased noticeably over the past few years. From a per capita level of 0.69 kilograms in 1998, it grew to 1.57 kilograms in 2005, at an annualized rate of about 1.2 percent per annum, before falling slightly in 2006 (Figure 3). For example, U.S. consumption of fresh avocados has more than doubled since 1998, from 192,0000 tons in 1998 to 465,000 tons in 2006 (USDA 2007). Several factors are responsible for the increased U.S. consumption of avocados, in

Evans is assistant professor and Nalampang is research assistant, Tropical Research and Education Center, University of Florida, Homestead.

Table 1. World's Top 10 Avocado Producers, 1996–2006 (Thousand Metric Tons).

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Share (percent)
Mexico	838	762	877	879	907	940	901	905	987	1,022	1,137	34.27
USA	173	161	145	166	217	203	181	212	163	256	247	7.45
Indonesia	143	130	131	126	146	142	238	256	222	228	228	6.86
Colombia	114	126	74	159	132	137	145	162	174	186	186	5.60
Brazil	81	84	84	86	86	154	174	157	171	169	169	5.11
Chile	60	55	99	82	98	110	140	140	160	163	163	4.91
Dominican Rep.	100	90	85	71	82	111	148	274	219	114	114	3.43
Peru	64	73	68	79	84	93	94	100	108	103	103	3.12
China	47	50	53	72	72	77	77	84	87	88	90	2.71
Ethiopia	74	75	76	77	78	79	80	81	82	83	83	2.51
World total	2,394	2,335	2,430	2,556	2,673	2,823	2,943	3,134	3,144	3,267	3,317	100

Source: FAOSTAT (n.d.)

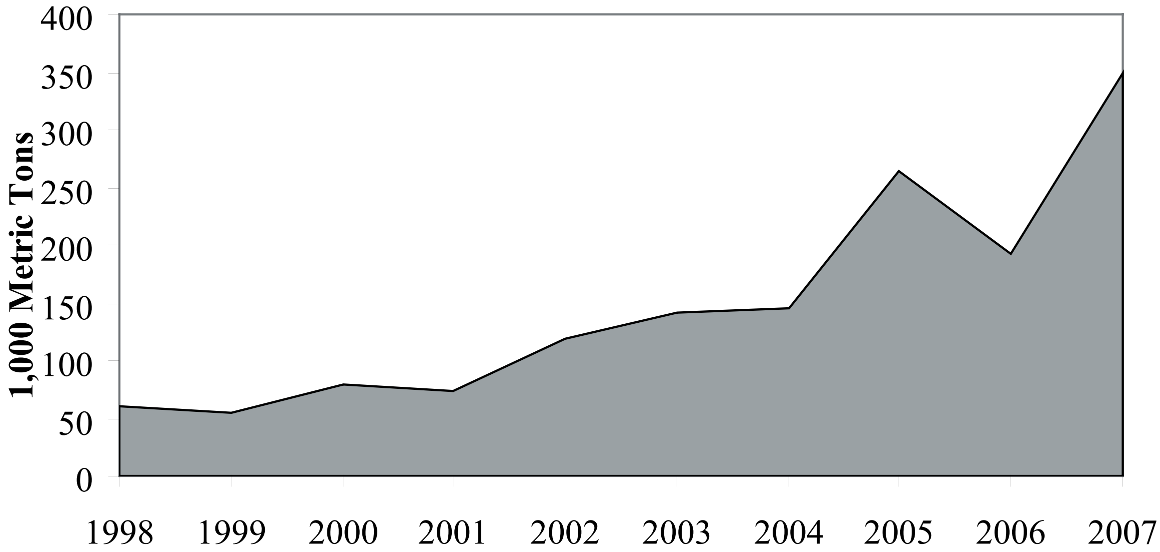

Figure 1. Total U.S. Avocado Imports, 1998–2007 (Thousand Metric Tons).

Source: USDA-FAS (2007).

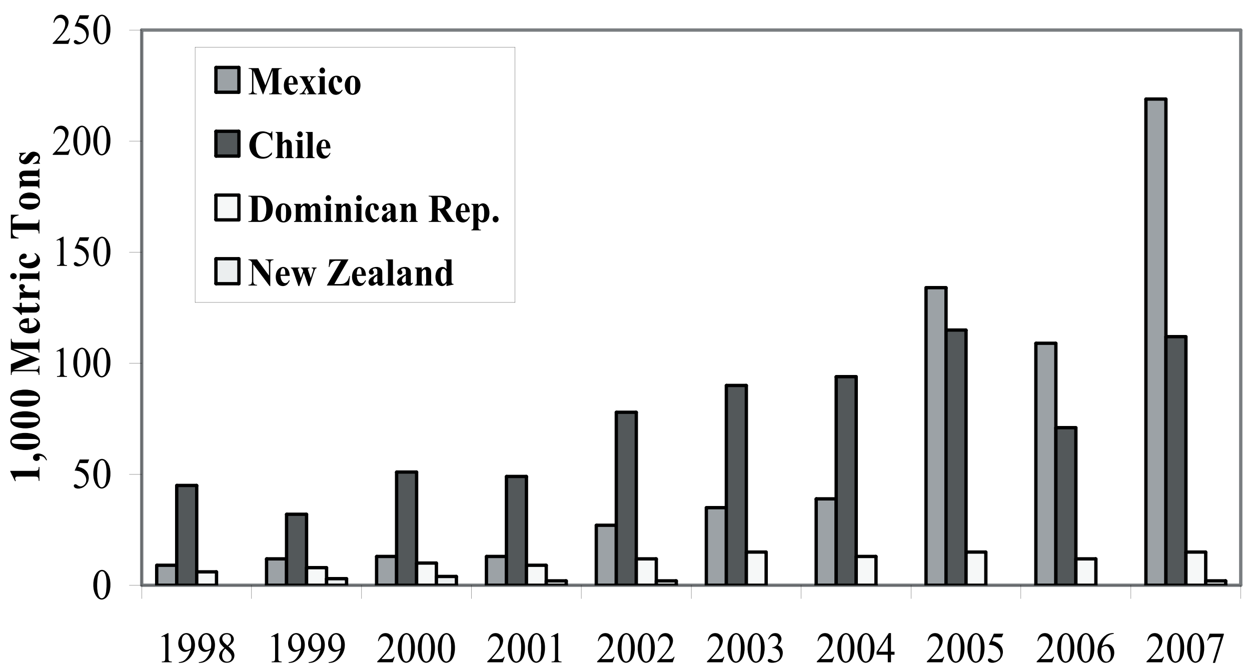

Figure 2. Top Four Exporters of U.S Avocado Imports, 1998–2007 (Thousand Metric Tons).

Source: USDA-FAS (2007).

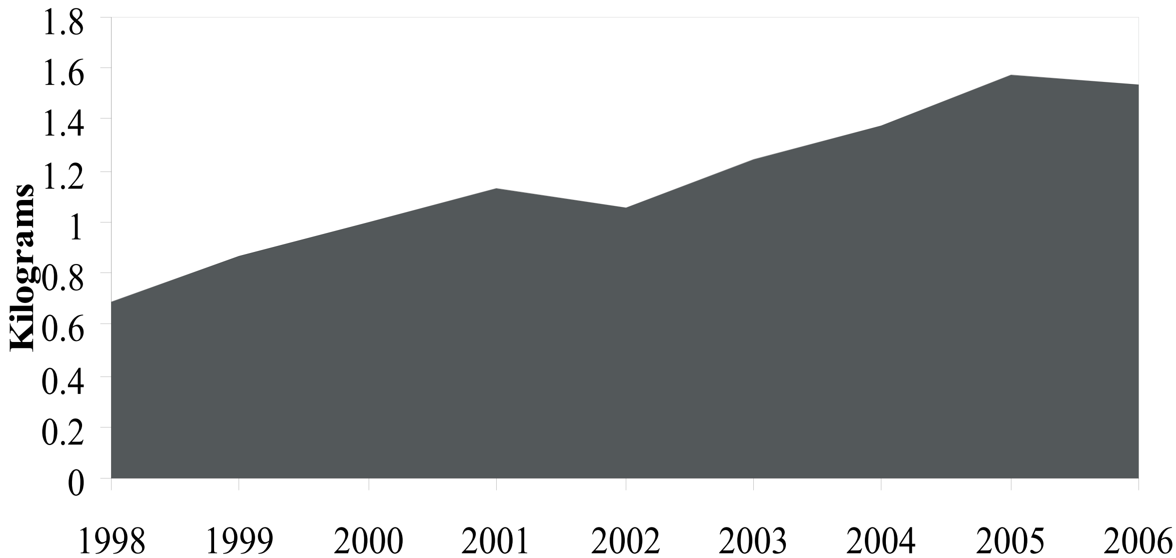

Figure 3. Per capita Consumption of U.S. Avocado, 1998–2006 (Kilograms).

Source: USDA (2007).

particular a rapidly growing U.S. Hispanic population. Hispanics are the largest and fastest-growing ethnic segment in the United States, accounting for about 13 percent of the U.S. population in 2004 (Miller 2005; USDA 2006). Between 1996 and 2006, the general U.S. population increased by 6 percent, from 282 million to 300 million (about 0.6 percent per annum), whereas the Hispanic population increased by 24 percent, from around 35 million to 44 million (about 3.7 percent per annum) over the same period.

Other factors responsible for the increase in U.S. avocado demand include year-round availability of fresh avocados, promotion of the health benefits of avocados, and increased disposable income (Carman and Rodriquez 2004). Imports have increased the year-round availability of fresh avocados in local groceries, food markets, and restaurants. With consumers becoming more health conscious, the demand for healthier food items (functional foods) has increased. Research has demonstrated that avocados contain antioxidants known to slow the aging process and to protect against heart disease and various forms of cancer (Lopez et al. 1996; Lu et al. 2005). Taking advantage of such findings, the California Avocado Commission spent approximately $13 million on advertising and promotional activities in 2005. The focus of the promotion was aimed at proactively communicating the nutritional and health benefits of avocados through national public relations and outreach efforts. Another element has been the increasing disposable income of U.S. consumers. Between 1996 and 2006, per capita disposable income grew at an annualized rate of 2.1 percent, which meant that more consumers were willing to try new food products.

Due to the strong demand factors mentioned above, avocado prices trended upward for a while. The average price of U.S. avocados increased from around $0.45 per kilogram in 1993 to about $2.38 per kilogram in 1999. Avocado prices remained relatively stable between 1999 and 2005, but then began steadily trending downward. The 2007 price of $1.53 per kilogram was 10 percent below the five-year average of $1.70 per kilogram and 36 percent below that obtained in 1999 (Figure 4). This decline in prices, which has coincided with increased avocado imports from Mexico into the U.S.

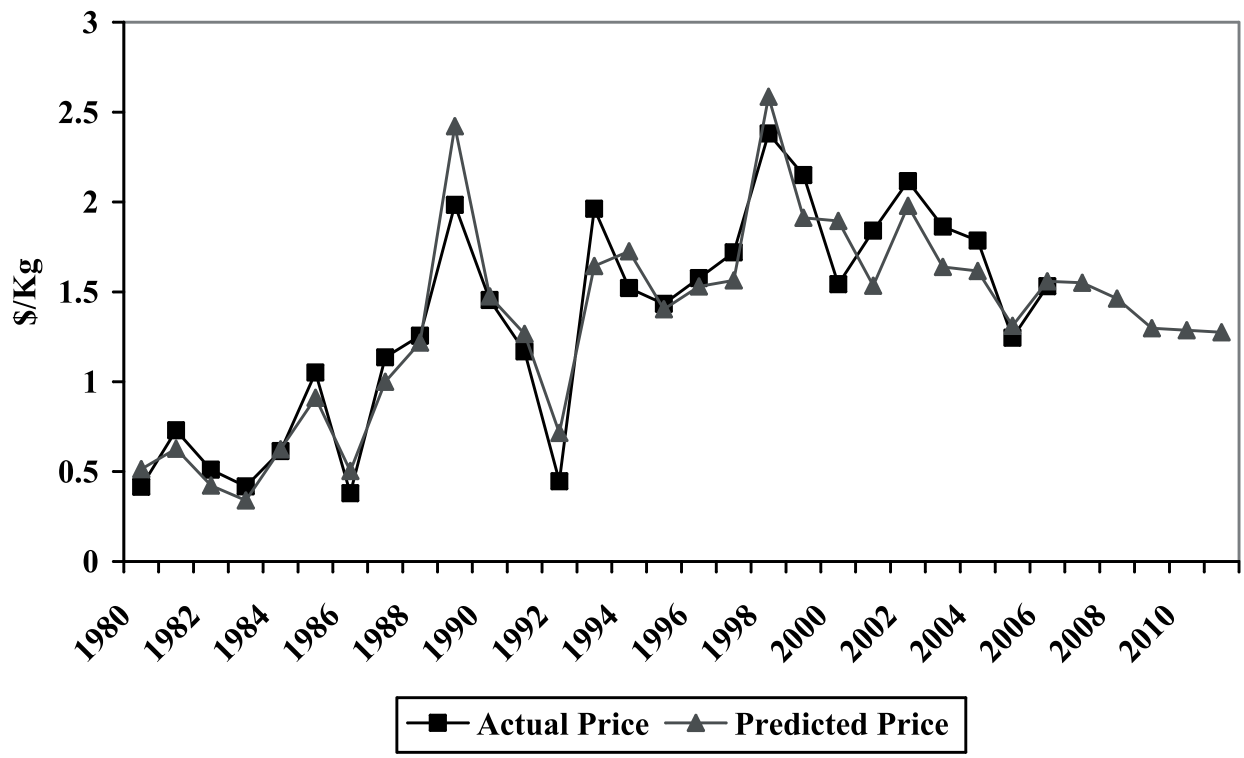

Figure 4. U.S. Avocado Actual vs. Predicted Price, 1980–2011 ($/kg).

market, prompted this investigation. Specifically, the concern is that further increases in the supply of imported avocados from Mexico and the softening of demand drivers could place severe downward pressure on prices in the U.S. market. This paper therefore aims at developing quantitative estimates of the demand parameters for U.S. avocados and which such specifications and assumptions regarding some of the main demand drivers to forecast the domestic prices in the near term.

Material and Methods

Model Specification

Conventional demand theory using the price-dependent, inverse-demand approach states that the price of a commodity is determined by per capita consumption of the commodity, the price(s) or per capita consumption of substitutes and/or complements, per capita income of consumers, and any taste changes. Per capita consumption of avocados and the price of any complement should vary inversely with the price of avocados, while price(s) of other fresh fruits and income, assuming the good is normal, should have a positive relationship with avocado prices.

The functional form for avocado retail price equations can be written as

(1) $P = f(Q_A, Q_{OF}, I, T)$.

The econometric specification of the price forecasting model is

(2) $\ln P_t = \alpha + \beta_1 \ln Q_{A,t} + \beta_2 \ln Q_{OF,t} + \beta_3 \ln I_t + \beta_4 \ln T_t + \varepsilon_t$,

where α is an intercept intercept, P_t is U.S. avocado price in year t, $Q_{A,t}$ is per capita consumption of avocado in the U.S. in year t, $Q_{OF,t}$ is per capita consumption of other fresh fruits in the U.S. in year t, I_t is per capita disposable income in year t, T_t is a trend variable, and ε_t is an error term.

This double log function provides the price and cross-price flexibilities. Data on U.S. avocado prices from 1980 to 2006 were obtained from the National Agricultural Statistics Service, United States Department of Agriculture. Per capita consumption of avocado in the United States and per capita consumption of other fresh fruits from 1980 to 2006 were obtained from the Economic Research Service, United States Department of Agriculture. Per capita disposable income from 1980 to 2006 was obtained from the Bureau of Economic Analysis, United States Department of Commerce.

Ordinary least squares regression was used to estimate the coefficients of the avocado price-forecasting model for the period 1980 to 2006 using SAS. Residuals of the avocado price-forecasting regression model were tested for autocorrelation and heteroscedasticity. Autocorrelation could exist if a time pattern in the residuals of a model were detected, but such findings would be undesirable due to biases in the standard-error estimates for the coefficients. The Breusch-Godfrey test, also known as the Lagrange Multiplier (LM) test, was used to test for autocorrelation. This test, which is more powerful than the Durbin-Watson test, was used because higher-order autocorrelations were included in the LM test. Heteroscedasticity could exist if the variance of the residuals increased or decreased in a systematic manner. Heteroskedastic observations would be problematic because the estimated standard error of coefficients would also be biased. The Breusch-Pagan-Godfrey (BPG) test was used to test for heteroscedasticity problems.

Forecasting

Avocado prices for the 2007/2008 to 2011/2012 seasons are projected using the avocado price-forecasting regression model. In order to do so, it was necessary to provide future values for the exogenous variables in the forecasting equation. Such values can be obtained from other studies or by assuming that recent trends in the past will continue in the future. In this regard, it is assumed that per capita consumption of avocado and per capita consumption of other fresh fruits in the United States can be predicted using the exponential-growth data from the last three years. Predicted per capita disposable incomes from 2007 to 2011 are taken from IBIS World (n.d.).

In order to assess the predictive accuracy of the forecasting model, the performance of the model was evaluated in terms of the following forecast-evaluation statistics: mean error (ME), mean absolute error (MAE), mean-squared error (MSE), root mean-squared error (RMSE), and Theil's U-statistics. Theil's U-statistics are presented in both specifications of the model, and are labeled U_1 and U_2, respectively (Theil 1966). Denoting a series of corresponding actual outcomes as A_t and a forecast of it as F_t, the forecast error results in $e_t = A_t - F_t$, for $t = 1,...,T$, where T represents the number of observations. Using this notation, the set of forecast evaluation statistics considered are

$$(3)\quad ME = \frac{1}{T}\sum_{t=1}^{T}(A_t - F_t) = \frac{1}{T}\sum_{t=1}^{T} e_t \ ,$$

$$(4)\quad MAE = \frac{1}{T}\sum_{t=1}^{T}\left|A_t - F_t\right| = \frac{1}{T}\sum_{t=1}^{T}\left|e_t\right| \ ,$$

$$(5)\quad MSE = \frac{1}{T}\sum_{t=1}^{T}(A_t - F_t)^2 = \frac{1}{T}\sum_{t=1}^{T}(e_t)^2 \ ,$$

$$(6)\quad RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(A_t - F_t)^2} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(e_t)^2} \ ,$$

$$(7)\quad U_1 = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(A_t - F_t)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}A_t^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}F_t^2}} = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(e_t)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}A_t^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}F_t^2}} \ ,$$

$$(8)\quad U_2 = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(A_{t+1} - F_{t+1})^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(A_{t+1} - A_t)^2}} \ .$$

The mean error (ME) provides information on the long-term performance. A low ME is desirable, as the closer ME is to zero, the more accurate the estimate. A positive ME value gives the average amount of overestimation in the calculated values, while a negative ME suggests underestimation (Tomek and Robinson 2003). A simple way to avoid the compensation of positive and negative forecast errors is to consider mean absolute error (MAE). The MAE gives the absolute value of the bias errors. Although the MAE is more resistant to outlier errors, the mean squared error (MSE) is more often used in practice. A MSE of zero represents a perfect forecasting model. However, because the MSE is simply relative to zero, no benchmark level of the MSE exists to tell a forecaster when the model is no good. An alternative means of examining the size of forecast errors is the root mean square error (RMSE). The RMSE test gives information on the short-term performance of the correlations by allowing a term-by-term comparison of the actual deviation between the estimated and measured values. The lower the RMSE, the more accurate is the estimate. However, the RMSE is limited because it does not distinguish between under- and over-predictions. Also, there is no theoretical upper bound for the RMSE (Tomek and Robinson 2003).

Like RMSE, Theil's U-statistics cannot distinguish between under- or over-prediction, but the magnitude of error can be examined from the inequality coefficients (U). U will be zero when the forecast is perfect. The statistic U_1 is bounded to the intervals 0 and 1. A value of 0 for U_1 indicates perfect prediction, while a value of 1 corresponds to perfect inequality or negative proportionality between the actual and predicted values. This means that the more accurate the forecast, the lower the value of the U_1 statistic (Tomek and Robinson 2003).

Statistic U_2 is bounded by 0, the same as U_1, with perfect forecasts. A U_2 value of 1 indicates that forecasts are no better than the naïve no-change extrapolation. However, it has no upper bound and takes on a value of 1 when the prediction method is the no-change extrapolation. Consequently, U_2, as opposed to U_1, can take on values greater than 1 for models less accurate than no-change extrapolations. Therefore numbers closer to zero are preferred to numbers farther away.

Results

Results for the econometric estimation are shown in Table 2. Overall, the adjusted R-squared term suggests that these equations fit the data (more than 90 percent of the variation around the mean of each series is explained by its respective regression). The coefficient for the quantity of avocado is statistically significant, with the own-price flexibility at −1.658. It indicates that a one-percent increase in the supply of avocados in the market is likely to cause the price of avocado to decrease by 1.658 percent. The coefficient for per capita disposable income is 6.915 and is statistically significant. It indicates that a one-percent increase in per capita disposable income is likely to cause the price of avocado to increase by 6.915 percent. The coefficient for trend, which is a dummy variable for technology, is −0.510 and is statistically significant. Only the coefficient of other fresh fruits (cross-price flexibility) is not statistically significant. Residuals of the regression model are tested for autocorrelation and heteroscedasticity. The results do not indicate whether the avocado price-forecasting model exhibits statistically significant autocorrelation (Pr > LM, 0.2134) or heteroscedasticity (Pr > Chi Square, 0.259). In a forecasting model, the ability to predict turning points is obviously important. The actual values and predictions from the avocado price-forecasting model are shown in Figure 4. The avocado price-forecasting model can predict all turning points. In addition, all forecast evaluation statistics are very low (Table 3), meaning that the price forecasts from the avocado price-forecasting model are highly reliable.

Discussion

As illustrated in Figure 4, the avocado price-forecasting model tracks the actual price fairly accurately. Based on the assumptions made, the model predicts that prices are likely to fall from $1.55 per kilogram in the 2007/08 season to about $1.30 per kilogram in the 2009/10 season, and may subsequently stabilize at around $1.28 per kilogram, a decrease of about 18 percent (Table 4). The predicted decline in price is due to a combination of increased supplies and weakened demand conditions. Although domestic production is expected to lessen, after taking into account fluctuation bearing years, imports are ex-

Table 2. Avocado Price Model Regression Estimates for U.S. Avocado, 1980–2006.

Variable	Coefficients	Standard error	t-value	Pr > |t|
Intercept	−72.029 (α)	9.373	−7.68	<0.0001
ln Q_A	−1.658 (β_1)	0.193	−8.58	<0.0001
ln Q_{OF}	0.999 (β_2)	1.154	0.87	0.3957
ln I	6.915 (β_3)	1.026	6.74	<0.0001
ln T	−0.510 (β_4)	0.153	−3.34	0.003
Multiple R	R^2	Adjusted R^2	Standard error	Observations
0.957	0.916	0.901	0.181	27
ANOVA				
	Degree of freedom	Sum of square	Mean square	F-value
Regression	4	7.876	1.969	60.245
Residual	22	0.719	0.033	
Total	26	8.595		
Heteroscedasticity test				
Test	Statistic	Degree of freedom	Pr > chi square	
White's test	23.62	14	0.0509	
Breusch-Pagan	5.29	4	0.259	
Godfrey's serial correlation test				
Lagrange multiplier	Pr > LM			
1.55	0.2134			

Table 3. Forecast Evaluation Statistics.

Evaluation measures	Statistics
Mean error (ME)	−8.10E-15
Mean absolute error (MAE)	0.1304
Mean squared-error (MSE)	0.0266
Root mean-squared error (RMSE)	0.1632
Theil's U_1 statistic (U_1)	0.0974
Theil's U_2 statistic (U_2)	0.3061

Table 4. Avocado Price Model Forecasts, 2007–2011.

Season	Price ($/Kg)	Per capita consumption (Kgs)		Per capita personal disposable income ($)
		Avocado	All other fresh fruits	
2007/08	1.550	1.659	43.508	28,649
2008/09	1.464	1.748	43.114	28,878
2009/10	1.299	1.841	42.723	28,849
2010/11	1.288	1.940	42.335	29,282
2011/12	1.276	2.043	41.951	29,721

pected to continue their upward trend. This trend is expected to continue despite expected reductions in shipments of avocados from Chile (USDA 2007). The weak U.S. dollar will encourage Chilean exporters to pursue more lucrative EU markets where the exchange rate is much higher and markets are less saturated. However, supplies coming to the United States from Mexico will more than offset such declines. Mexico is becoming a stronger export source based on increased acreages of new bearing trees, the adoption of good agricultural practices to control pests, more municipalities obtaining certification to export to the United States, and the elimination of restricted harvesting (USDA-FAS 2007). Under the restricted harvesting program, producers had agreed to restrict the amount of avocados they harvest per acre so as not to saturate the export market and cause prices to fall. With the removal of this restriction, it is expected that growers will increase their harvest from two tons per hectare to 10 to 15 tons per hectare (USDA 2006).

On the demand side, there is expected to be a severe weakness in the main drivers of avocado consumption in the United States because avocado is not a U.S. staple crop. Lower per capita disposable income in the United States is expected to severely hamper the growth rate of avocado consumption in the United States among consumers who are willing to experiment with the commodity. Aggressive promotion of the health benefits by various avocado associations might counter some of the effects of the rising costs of energy and essential commodities (USDA-APHIS 2004; Carman and Rodriquez 2004). Likewise, continued growth in the Hispanic population, albeit at a much slower pace due to more stringent immigration policies, may aid in offsetting some of the negative impacts of inflation on commodity demand (USDA-NASS 2004; Carman and Rodriquez 2004). On the basis of the above mix of factors influencing demand, our model forecasts that over the near term avocado prices in the U.S. domestic market are not likely to recover (rise) to those obtained recently, but with proper advertisement, the decline may not be too severe.

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