Analysis of U.S. Demand for Imported Melons using a Dynamic Almost Ideal Demand System

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Abstract

Melons constitute an important part of the U.S. fruit and vegetable industry even though they are produced only from May through December of each year. Import supplies from Latin American countries are used to make up for the domestic demand shortages. This paper investigates the U.S. demand for imported fresh and frozen melons using quarterly data on import volumes and unit prices. A static and a dynamic linear approximated almost ideal demand systems were estimated using ITSUR. Marshallian and Hicksian elasticities were used to analyze consumers' responsiveness to price and income change in the short run and the long run.

Keywords: Melons, Demand Analysis, Dynamic AIDS, U.S.

Introduction

The United States is one of the world's leading consumers and producers of melons concomitantly. ERS report (2008) depicted that, melons which includes cantaloupe, honeydew and watermelons were amongst the top five ranking vegetables and fruits crops in the USA. Several factors have contributed to the increased per capita consumption of melons. Amongst the most important are the health attributes and "health consciousness of consumers, improved year-round availability, creative marketing and improved varieties". Although per capita consumption of all categories of melons in 2010 was estimated to 27.1 pounds the breakdown of the popular U.S. varieties depicted that watermelon was 15.6 pounds, cantaloupe 9.3 pounds and honeydew 1.7 pounds (Kaninda and Fonsah, 2012; ERS, 2010). One study shows that although watermelons consumption has dominated the melons category, particularly cantaloupe and honeydew due to its weight advantage, empirically and statistically, more cantaloupes are being sold per unit than watermelon (Borris and Keith, 2006).

The Chinese continue to dominate the worlds' melon production. Other important world producers are Turkey, Iran and Brazil in the 2nd, 3rd, and 4th position while the United States is ranked 5th. On the other hand, the U.S. is the 3rd largest producer of cantaloupe in the world, after China and Turkey in the 1st and 2nd place respectively. In the past half a decade, the value of U.S. melons have increased by almost 25%. The combined watermelon, cantaloupe and honeydew value rose from over $703.1 million in 2004 to $878.8 million in 2009 (NASS, 2010).

Nationally, California, Arizona, Texas, Georgia, and Florida are the top producers of melons due to their climatological advantage vis-à-vis other states. Studies have shown that. "California is the leading U.S. producer of all melons with 33% of total acreage, followed by

Texas 14.4%, Georgia 11.7%, Arizona 10.5% and Florida 9.8% respectively. In terms of acreage and weight, California is the leading state in the production of cantaloupe and honeydew, whereas Florida is the leader in watermelon production (Borris and Keith, 2006; Kaninda and Fonsah, 2012).

Since domestic demand is greater than supply, and the fact that most melon production in the U.S. is only possible from May through December, import demand activities from Latin American countries to fill the gap occur between December and May (Jesus, Fuller and Malaga, 1998; Jesus, Fuller and Malaga, 2000).

Like other horticultural crops, imported melons have become an integral part of the U.S. supply chain. For instance, the values of imported melons have increased by 360% from 1989 when it was worth \$129 million to \$467.5 million in 2009. The value of imported cantaloupe rose 209 %, i.e. from \$71.6 million to \$149.9 million while watermelon increased 990%, i.e. from \$22.2 million to \$219.7 million respectively (ERS, 2010). The major suppliers of melons to the United States are Mexico, Guatemala, Costa Rica and Honduras. Mexico has position herself as the leader with 44% of total suppliers, followed by Guatemala with 29% and Costa Rica (Jesus et al, 2000; AgMRC, 2010). This study investigates the U.S. demand for imported fresh and frozen melons using quarterly data on import volumes and unit prices. A static and a dynamic linear approximated almost ideal demand systems were estimated using ITSUR. Marshallian and Hicksian elasticities were used to examine consumers' responsiveness to price and income change in the short run and the long run.

The organization of this paper is as follows. Section two presents the theoretical model, followed by model specification. Estimation procedure and empirical results will be presented in section four. Finally, the last section focuses on summary and conclusion.

Theoretical model

The Almost Ideal Demand System (AIDS) model was developed by Deaton and Muellbauer (1980). Since then, several researchers have been using it in consumer demand analyses due to its flexible functional form (Green and Alston, 1990; Hayes Wahl and Williams, 1990; Chalfant, 1987). In addition, the last three decades has been dominated by the use of the AIDS model in the consumer demand literature in general and food demand studies in particular (Walud, 2006; Balagtas, Coulibaly and Diarra, 2006; Thompson, 2004; Piggott and Marsh, 2004). Fresh fruit and vegetable in general and imported fruit and vegetable in particular are consumed as final goods. For that reason, the AIDS model instead of a production model is used in the analysis of melons imports for these commodities (Nzaku, Houston and Fonsah, 2010).

Furthermore, the wide use of the AIDS model in demand analyses can be justified by the fact that many empirical analyses have shown that the AIDS model fits consumer demand analyses better than the Rotterdam model (Ahangarani and Souri 1999; Timidas, 2000; Mekonnen, Fonsah and Borgotti, 2011).

These studies include the work of Taljaard, Alemu and Schalkwyk, (2006); Jung and Koo (2000), and Jabarni,(2005),Jung and Koo, 2000; Jabarni, 2005; and Taljaard, Schalkwyk and Alemu, 2006).

Model specification

The general form of the AIDS model is as follows:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{M}{P}\right) + \mu_i \tag{1}$$

Where α_i, γ_{ij}, β_i are the parameters (i, j= 1,….n), n is the number of products in the system, w_i is the budget share of commodity i, p_j is the price of commodity j, M is the total expenditure on all the commodities, and P represents the value of a price index, which is defined as:

$$\ln P = \alpha_0 + \sum_k \alpha_k \ln P_k + \frac{1}{2} \sum_k \sum_j Y_{ij}^{*} \ln P_i P_j \quad (2)$$

The use of this price index does not allow for a linear estimation of the demand system. Therefore, in the estimation of the AIDS model the, the stone's price index is used for a linear approximation of the AIDS model. An AIDS model in which a linear price index is used is referred to as the linear approximation of the Almost Ideal Demand System (LA/AIDS) (Mohanty and Peterson, 1999; Kaninda and Fonsah, 2012). The Stone price index is given by:

$$\log(P) = \sum_{i=1}^{n} W_i \log(P_i) \quad (3)$$

Where W_i is the budget share of each good being used as a weight.

To be consistent with the demand theory, the following restrictions must be satisfied: adding up, homogeneity i and symmetry (Deaton and Muellabauer, 1980; Taljaard and Scalkwyk, 2006; Balagtas, Coulibaly and Diarra, 2006),

Adding-up: $\sum \alpha_i = 1,\ \sum_i \gamma_{ij} = 0$ and $\sum_i \beta_i = 0$; (4)

Homogeneity: $\sum_j \gamma_{ij} = 0$; (5)

Symmetry : $\gamma_{ij} = \gamma_{ji}$ (6)

α_i, β_i and γ_{ij} are parameters. α_i is the estimated budget share of commodity i. β_i represent the commodity expenditure coefficient. It determines the variation of good i's expenditure when the real income changes. The γ_{ij}'s are the price coefficients. They determine how the budget share of good *i* changes due to a percentage change in the price of good *j* holding the real expenditures constant (Kaninda and Fonsah, 2012).

Due to the flexible functional form of the LA/AIDS model, we can easily carry out the elasticity analysis. The different elasticities can be computed from the following formulas:

$\eta_i = 1+\beta_i/w_i$, for the expenditure or income elasticity, $\varepsilon_{ij}^{M} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_j w_i}{w_i}$ for the Marshaillian elasticities and $\varepsilon_{ij}^{H} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} + w_i$ for the Hicksian elasticity,

where δ is the Kronecker delta, $\delta_{ij} = 1$ for i=j and $\delta_{ij} = 0$ if $i \neq j$.

As specified in equation (1), the AIDS model doesn't take into account the time series of the data. Such a model is known as a static or long run model. The Static model is based on the assumption that consumers' behaviors do not change or vary with the time horizon. In other words, there is no difference between consumers' short run and long run behavior, implying that, consumers' behavior is always in equilibrium (Anderson and Blundell, 1983; Sulghan and Zapata, 2006).

However, in reality, factors such as, habit formation, adjustment costs, imperfect information and incorrect expectations may cause some adjustment time to changes in prices and consumer income (Jaffry and Brown, 2008). Hence, until full adjustment takes place, consumers are out of equilibrium (Sulghan and Zapata, 2006). The non investigation of the time series properties of the data used in the demand studies may be the cause of the inconsistency between the theory and the data used in consumer demand analyses. (Karagiannis and Mergos, 2002; Sulghan and Zapata, 2006).Therefore, it is important to take into account the time series properties of the data for the consistency of the estimated parameters.

To investigate the time series properties of the data, each time-series should be tested for stationarity. The augmented Dickey-Fuller (ADF), the Phillips-Perron and the Johansen test can be used to identify the number of unit roots and determine the order of integration. Once the order of integration is identified, cointegration can be tested among the variables in the model (Zahedi, 2006; Nzuma and SaRker, 2010). If cointegration is established between the dependent variables and the linear combination of independent variables, an error correction model version of the LAIDS (ECM-LAIDS) can be estimated. The ECM-LAIDS model can be specified (Nzuma and SaRker,2010, Karagiannis and Mergos,2002) as;

$$\Delta W_i = \alpha_i \Delta W_{it-1} + \sum_i^n \gamma_{ij} \Delta \ln p_{jt} + \beta_i \Delta \ln \left(\frac{M_t}{P}\right) + \lambda_i U_{it-1} + \varepsilon_t, \quad (8)$$

where, Δ represents the difference operator, U_{it-1} are the estimated residuals from the cointegration equations, and λ_i is expected to be negative.

Estimation and Empirical Results

Quarterly observations over the period 1989(1) to 20010(3) were used for this study. Import volumes and unit prices data were from the United States Department of Agriculture (USDA), Economic research Service (ERS).

We first estimated the static model as specified in equation (1) by incorporating trigonometric and a time trend variables to capture seasonality. The modified static AIDS model can be then specified as (Nzaku, Houston and Fonsah, 2010):

$$w_i = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln p_j + \beta_i \ln \left(\frac{M}{P}\right) + \sum_{u=1}^4 \alpha_{1iu} f_u + \sum_{v=1}^4 \alpha_{2iv} g_v + t_i trend + \mu_i \quad (9)$$

Where $f_u = \cos(\frac{u}{z}\pi_t)$ and $g_v = (\frac{v}{z}\pi_t)$ are seasonal functions, Z equals *S*/2 and S is the frequency of data. Given that we use quarterly data, S=4 and Z=2. The variables v and u represent the seasonal frequency of data and t is the time trend.

To avoid singularity in the covariance matrix, the equation of frozen melon was dropped from the system. The parameters of the dropped demand equation were estimated using the adding up restriction. In addition, an iterative seemingly unrelated regression (ITSUR) procedure was used to estimate the different demand systems. Furthermore, homogeneity and symmetry were imposed in the estimation process.

The estimated results from the static model are reported in Table1. The expenditure parameters of fresh cantaloupe and fresh watermelon are positive and statistically significant at 1% level, suggesting that there are luxury goods. However, other fresh melons and frozen melons are necessity goods owing their negative expenditure coefficients. In addition, seasonality plays an important role in the demand of all the commodities, given that all the commodities have at least one significant seasonal component parameter. Furthermore, the trend coefficients reveal that the import budget share for fresh watermelon has been increasing over the study period, while it has been decreasing for the other commodities.

The estimated parameters were used to estimate demand elasticities contained in Tables 2 and 3.

In order to investigate the time series properties of the data, the augmented Dickey-Fuller test was used. The test results reported in table 4 show that except for other fresh melon budget share, all the variables contained a unit root at 5% significance level. When first differences were used, we found that all tested variables were integrated of order1, I (1) (Table5).

Having established the order of integration, we then tested for cointegration between the variables in the static model using the Phillips-Perron test. Based on the results reported in Table 6, all the budget shares are cointegrated with prices and expenditure. As a results, the dynamic AIDS model as specified in equation (8) is estimated in order to capture the short terms relationship between the variables.

The estimated parameters of the dynamic model are reported in Table7. As In the long-run, the expenditure coefficients for fresh cantaloupe and fresh watermelon are positive and statistically significant at 1%, implying that these commodities are luxury goods while other fresh melons and frozen melons are necessity goods due to their negative expenditure coefficients.

All the error correction term coefficients, λ_i, are statistically significant and have the correct sign. The different parameters were used to estimate the elasticities reported in Tables 8 and 9. All the own-price elastiticies are negative as expected, both in the short and the long-run, thus, satisfying the law of demand. The estimated Marshallian own-price elasticities from the static model were -0.75014, -1.23, -0.514 and -0.473 for fresh cantaloupe, fresh water melon, other fresh and frozen melons respectively (Table 2). Except for fresh watermelon, all the commodities were price inelastic in the short run suggesting that a 1% increase in their prices would result in a less than 1% decrease in their respective budget shares. For instance, a 1% increase in the price of fresh cantaloupe would lead to a 0.75% decrease in the budget share for imported fresh cantaloupe. Likewise, all the short run own-price elasticities are negative, however, all of them are less than 1. The estimated   Marshallian own-price elasticities from the dynamic model were -0.774, for fresh cantaloupe,-0.488 for fresh watermelon, -0.359 and -0.321 for frozen melons (Table 8).

Based on Marshallian elasticities, except for fresh cantaloupe, all long-run own-price elasticities are larger in absolute value than those in short-run, implying that consumers were more responsive to price change in the long-run than in the short-run.

Over all, the expenditure elasticities for the different commodities are positive in the short and meaning that these commodities are normal goods. However, in the long-run,frozen melons are considered as inferior goods These elasticities range from 0.1751 for frozen melons to 1.26 for fresh watermelon in the long-run (Table2). In the short-run the expenditure elasticities vary from -0.034 for frozen melons to 1.21 for fresh cantaloupe (Table 8). In addition, fresh cantaloupe and fresh water melon are expenditure elastic both in the short and the long-run, suggesting that these commodities are considered as luxury goods.

The Hicksian elasticities reported in tables 6 and 9 reveal that fresh cantaloupe, fresh watermelon and other fresh melons are net substitutes both in the short and the long-run. However, other fresh melons and frozen melons are net complements in the long-run. Furthermore, fresh cantaloupe, fresh watermelon and other fresh melons are net complements with frozen melons in the long-run.

Conclusion

The purpose of this paper was the investigation of the U.S. demand for imported fresh and frozen melons using quarterly data on import volumes and unit prices. A static and a dynamic linear approximated almost ideal demand systems were estimated using ITSUR.

Elasticities from the static and the dynamic model were estimated and used to analyze consumers' responsiveness to price and income changes both in the short and the long run.

All own-price elasticities were negative, both in the short and the long-run conforming to demand theory. The Marshallian own-price ealsticities in the short-run ranged from -0.32 for frozen melon to -0.77 for fresh cantaloupe. In long run, they varied from -0.47 for frozen melons to -0.125 for fresh watermelon. Except for fresh watermelons, all the commodities were price inelastic both in the short and the long-run. In addition, with the exception for cantaloupe, long-run own price elasticities were larger in absolute value than their short run counterpart, suggesting that consumers were more price sensitive in the long-run than in the short run.

Based on expenditure elasticities, consumers considered fresh cantaloupe and fresh watermelon as luxury goods both in the short and long-run and other fresh melons as necessity goods. Frozen melons were considered as necessity goods in the short-run but inferior goods in the long-run.

Furthermore, the estimated Hicksian elasticities show that almost all the commodities are net substitutes except for other fresh melons and frozen melons which are net complement in the long run. In the short-run, all the fresh melons are net substitutes but they are net complement with frozen melons.

This study can serve as a reference for exporting countries and U.S. retailers in pricing strategies for the different melons as well for U.S. decision makers in charge of tax and trade policies. The combination of the inelastic own price elasticity and the elastic expenditure elasticity should encourage exporting countries and U.S. retailers to produce and import more fresh cantaloupe both in the short and the long-run. This is also the case for fresh watermelon in the short-run.

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Table 1: Estimated parameters for the static LA/AIDS model

Parameter\Commodity	Fresh Cantaloupe	Fresh Watermelon	Other fresh melons	Frozen Melons
α_i	-0.15887	-0.69311*	0.84653*	1.005451
	(-1.45)	(-4.37)	(6.15)	
γ_{i1}	0.125*	-0.0584*	-0.0239	-0.0427
	(8.22)	(-3.25)	(-1.46)	
γ_{i2}	-0.05843*	-0.04321	0.09343*	0.008204
	(-3.25)	(-1.06)	(2.86)	
γ_{i3}	-0.0239	0.093431*	0.1557*	-0.22531
	(-1.46)	(2.86)	(3.89)	
γ_{i4}	-0.04279*	0.008204	-0.225*	0.25989
	(-2.88)	(0.28)	(-8)	
β_i	0.0593*	0.06104*	-0.0248**	-0.09558
	(6.6)	(5.04)	(-2.29)	
Sin	0.05954**	-0.1144*	0.016843	0.038014
	(2.64)	(-3.83)	(0.64)	
Cos	0.032843**	-0.0339**	0.0528*	-0.05174
	(2.62)	(-2.01)	(3.53)	
t	-0.0025*	0.00348*	-0.0008***	-0.00012
	(-6.63)	(6.3)	(-1.74)	

t- Statistics in parentheses,
1= cantaloupe, 2= watermelon, 3= other fresh melons and 4=frozen melons

Table 2: Marshallian Long-run Price and Expenditure Elasticities of US Import Demand for fresh and frozen melons

Commodity\prices	Fresh Cantaloupe	Fresh Watermelon	Other Fresh	Frozen	expenditure
Fresh Cantaloupe	-0.75014*	-0.28454*	-0.08216**	-0.13086*	1.1806*
	(-15.57)	(-5.1)	(-1.99)	(-3.27)	(49.9)
Fresh Watermelon	-0.4658*	-1.23173*	0.361635**	0.003947	1.2585*
	(-4.84)	(-6.61)	(2.74)	(-1.02)	(27.91)
Other Fresh	-0.01246	0.367737*	-0.51411*	-0.7477*	0.9071*
	(-0.19)	(3.07)	(-3.3)	(-6.21)	(37.33)
Frozen	-0.52133**	0.266418	-2.2191*	-0.47342	0.1751
	(-2.82)	(-0.67)	(-6.02)		

Source: computed by the authors
t- Statistics in parentheses

Table 3: Hicksian Long-run Price and Expenditure Elasticities of US Import Demand for fresh and frozen melons

Commodity\prices	Fresh Cantaloupe	Fresh Watermelon	Other Fresh	Frozen	expenditure
Fresh Cantaloupe	-0.28461*	0.0901***	0.23612*	-0.0269	1.180628*
	(-7.40)	(1.92)	(5.66)	(-0.67)	(72.54)
Fresh Watermelon	0.15516***	-0.63003*	0.66421*	-0.0243	1.2585*
	(1.92)	(-3.55)	(4.96)	(-0.2)	(27.9)1
Other Fresh	0.35578*	0.581807*	-0.2697***	-0.66787*	0.907*
	(5.66)	(4.96)	(-1.71)	(-5.55)	(37.33)
Frozen	-0.1241	-0.06518	-2.04476*	-0.41648	0.1751
	(-0.67)	(-0.2)	(-5.55)		

Source: computed by the authors
t- Statistics in parentheses

Table 4: Unit root tests on level of variables

	W1	W2	W3	W4	Lnp1	Lnp2	Lnp3	Lnp4	Lnxp
Test statistic	-2.029	-2.64	-3.68	-2.601	-1.611	-1.517	-0.717	-1.826	-2.406
Critical value	-2.904	-2.9	-2.9	-2.904	-2.904	-2.904	-2.904	-2.904	-2.904
p-value for Z(t)	0.274	0.264	0.005	0.0928	0.4835	0.525	0.8423	0.368	0.1401

Source: computed by the authors
- Critical value at 5%
-W= budgets share, 1= fresh cantaloupe, 2=fresh watermelon, 3=other fresh, 4=frozen melons
- P= price

Table 5: Unit root tests on first difference variables

	W1	W2	W3	W4	Lnp1	Lnp2	Lnp3	Lnp4	Lnxp
Test statistic	-5.8	-5.1	-5.39	-6.206	-6.944	-5.648	-5.566	-6.344	-5.946
Critical value	-2.905	-2.91	-2.91	-2.905	-2.905	-2.905	-2.905	-2.905	-2.905
p-value for Z(t)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: computed by the authors
-Critical value at 5%

Table 6: Unit root tests on the level of estimated residual of the static model

	W1	W2	W3	W4
Test statistic	-9.392	-8.96	-9.44	-10.7
Critical value	-1.95	-1.95	-1.95	-1.95
p-value	0.000	0.000	0.000	0.000

Source: computed by the authors

Table 7: Estimated Parameters for the dynamic LA/AIDS model

Parameter\Commodity	Fresh Cantaloupe	Fresh Watermelon	Other fresh melons	Frozen Melons
α_i	-1.0499*	-0.32069*	0.266407*	1.104181
	(-8.41)	(-3.6)	(-3.68)	
γ_{i1}	0.128833*	0.001357	-0.05098*	-0.07921
	(-5.78)	(-0.09)	(-4.06)	
γ_{i2}	0.001357	0.109152*	0.031992	-0.1425
	(-0.09)	(-3.19)	-1.29	
γ_{i3}	-0.05098*	0.031992	0.176661*	-0.15767
	(-4.06)	(-1.29)	(-6.08)	
γ_{i4}	-0.07921*	-0.1425*	-0.15767*	0.379379
	(-3.35)	(-4.53)	(-5.68)	
β_i	0.086372*	0.026739*	-0.02205*	-0.09106
	(-8.45)	(-3.67)	(-3.72)	
λ_i	-1.13937*	-0.7999*	-1.06857*	
	(-5.13)	(-8.41)	(-11.71)	

t-statistics in parentheses

Table 8: **Marshallian short-run Price and Expenditure elasticities of US Import Demand for fresh and frozen melons**

Commodity\prices	Fresh cantaloupe	Fresh Watermelon	Other fresh melons	Frozen melon	Expenditure
Fresh Cantaloupe	-0.77464*	-0.04481	-0.17699*	-0.21804*	1.21449*
	(-12.73)	(-1.06)	(-5.48)	(-3.67)	(44.69)
Fresh Watermelon	-0.03382	-0.48887*	0.103654	-0.68896*	1.108
	(-0.46)	(-3.01)	(0.96)	(-4.47)	(31.86)*
Fresh Other	-0.14569*	0.135986	-0.35987*	-0.54705*	0.916624
	(-2.92)	(1.4)	(-3.14)	(-4.71)	(40.57)*
Frozen	-0.89245*	-1.57793*	-1.41854*	-0.32173	-0.03412
	(-3.25)	(-3.8)	(-3.98)		

Source: computed by the authors
t- Statistics in parentheses

Table 9: Hicksian short-run Price and Expenditure elasticities of US Import Demand for Fresh and frozen melons

Commodity\prices	Fresh cantaloupe	Fresh Watermelon	Other fresh	Frozen	Expenditure
Fresh Cantaloupe	-0.2813*	0.241984*	0.150422*	-0.1111***	1.21449*
	(-4.76)*	(5.85)	(4.75)	(-1.86)	(44.69)
Fresh Watermelon	0.416261	-0.22722	0.402359*	-0.5914*	1.108*
	(5.85)	(-1.42)	(3.71)	(-3.82)	(31.86)
Fresh Other	0.226653*	0.35244*	-0.11276	-0.46634*	0.916624*
	(4.75)	(3.71)	(-0.98)	(-4.02)	(40.57)
Frozen	-0.51254**	-1.585*	-1.42774*	-0.03412	-0.03412
	(-1.86)	(-3.82)	(-4.0)		

Source: computed by the authors
t- Statistics in parentheses