U.S. Citrus Import Demand: Seasonality and Substitution

Katherine L. Baldwin

Formerly of the Economic Research Service, United States Department of Agriculture
Washington, DC
Email: katherine.baldwin@usitc.gov; Telephone: (202) 205-3396

Keithly G. Jones

Animal Products and Cost of Production Branch, Market and Trade Economics Division,
Economic Research Service, United States Department of Agriculture
Washington, DC
Email: kjones@ers.usda.gov; Telephone: (202) 694-5172

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Abstract

Citrus fruits make up one-fifth of all fresh fruit consumed in the United States**.** Given the increasing importance of imported citrus in the diet of American consumers, it is perhaps surprising that no import demand analysis of U.S. citrus has been conducted. Using quarterly U.S. import data for six citrus commodities, we employed a demand systems model and evaluated aspects of seasonality. The results suggest wide variations in price responses to different types of imported citrus. The average amplitude and phase shift suggest that all citrus fruits exhibit some seasonality in their imports, likely a result of peak harvesting schedules of exporters.

Key words: Fresh citrus, oranges, limes, lemons, grapefruit, mandarins, import demand, seasonality

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Introduction

Although its share has been declining in recent years, citrus fruits make up one fifth of all fresh fruit consumed in the United States, with oranges (in fresh and juice form) alone accounting for nearly 10 percent of total per capita fruit consumption (USDA-ERS, 2010a). While per capita consumption of fresh citrus has declined since 1980, total U.S. consumption of citrus fruits has increased 20 percent since that time. Over the same period, total U.S. production of citrus fruits has been flat to declining, including the virtual disbandment of the U.S. commercial lime industry. In order to fulfill domestic fresh citrus demand, imported citrus has increased in importance, accounting for more than 20 percent of total domestic consumption in the 2009/10 crop year.

Given the increasing importance of imported citrus in the diet of American consumers, it is perhaps surprising that no detailed import demand analysis of the U.S. citrus market has been conducted to date. Large fluctuations in price could have negative consequences for the U.S. citrus industry, U.S. consumers, or both. Additionally, negative import demand reactions to changes in price could have serious economic consequences for those countries that export to the U.S. market – the majority of which are developing nations.

While citrus import demand studies have been conducted for other countries, (Lee, Seale, and Jienviriyapant, 1990; Torres, 1996; Schmitz and James L. Seale, 2002; Seale, et al., 2005; Feleke and Kilmer, 2009), none has looked at U.S. import demand for fresh citrus fruits. Sparks (1992) even pondered why there was such paucity of studies on fresh oranges, given its level of importance in

international trade. The paucity of research on fresh oranges has persisted into the 21st century, but this study seeks to fill this knowledge gap.

The overall objective of this article is to explore U.S. import demand characteristics for all major categories of fresh citrus imports – oranges, grapefruit, lemons, limes, mandarins, and miscellaneous citrus products – and to identify aspects of seasonality in imports. Specifically, although the different citrus fruits have various end uses (including direct consumption, flavoring agent, or even for juicing), the extent to which consumers substitute between citrus fruits for the various uses is not well understood, and we hope that this analysis sheds light on the degree of substitutability between products. In the next section, a brief overview of the U.S. citrus industry is provided. This is followed by an explanation of the approach used to model U.S. citrus imports. The data used in the model is then described, followed by the results and interpretation of the empirical estimates. The conclusions end the paper.

Citrus Industry Overview

Though often aggregated into the single "citrus" classification, each citrus fruit has a unique production, consumption, and trade back-story that can be used to help explain changes in import demand due to both own-price and cross-commodity price fluctuations. For all citrus products, imports into the U.S. are growing (see Figure 1). However, the relevance of imports to total consumption varies, and in some cases the share of consumption filled by imports has fluctuated very little over the past few decades.   A brief overview of the production, consumption, and import situations of each commodity is provided below.

Oranges

Although oranges comprise the bulk of U.S. citrus fruit production, most oranges are destined for juice production and therefore do not enter the fresh market (Perez and Pollack, 2002). During the 2009/10 marketing year, just over 25 percent of total U.S. orange production was destined for the fresh market. Although more than 70 percent of U.S.-grown oranges come from Florida, most Florida oranges are processed into juice. California dominates the fresh orange market – almost 85 percent of U.S. fresh-use oranges come from California, followed by Florida and Texas with 13 and 3 percent, respectively. Total fresh-use orange production tends to fluctuate around 2 million short-tons, with no clear upward or downward long-term trend.

Although production has been largely static since 1980/81, per capita consumption of fresh oranges has fallen nearly 24 percent. Declining consumption is largely a result of consumers preferring convenient, easy-to-consume fruits, and can also partially be attributed to greater availability of a wider array of fresh fruits in the marketplace. Despite static domestic production and declining per capita consumption, fresh orange imports have grown markedly in the past few decades. Fresh orange imports in 2009/10 were ten times higher than levels seen in 1980/81. Regardless, imports still only account for a minute 6 percent share of U.S. consumption, up from only 1 percent in 1980/81. The motivation for increased imports is largely a matter of seasonality. Peak import season begins in July after the end of the California navel season and ends in October when the harvesting of Florida's early-season varieties begins. South Africa, Chile, Mexico, and Australia are the top sources for U.S. orange imports. South Africa has been the largest supplier of fresh oranges to the U.S. market essentially since 2003. Its entrance into the U.S. market began with the 2000 passage of the African Growth Opportunity Act (AGOA), under which all imports of oranges from South Africa enter the U.S. duty-free. Interestingly,

the top four fresh orange suppliers receive preferential trade status, and all but South Africa export under free trade agreements.[1]

Grapefruit

Amongst all citrus fruits produced in the United States, grapefruit is unique in that both domestic production and consumption are falling. Indeed, the long-term decline in U.S. grapefruit production is a product of weak U.S. consumer demand. Even with declining domestic demand, the U.S. remains the world's second largest producer of grapefruit.

Around 70 percent of the U.S. grapefruit crop is grown in Florida, with Texas and California accounting for 20 and 10 percent, respectively. Bearing acreage has declined an average of 7 percent each year since 2005/06 in Florida, but seems to have stabilized in California and Texas. In total, U.S. grapefruit production has declined by 50 percent since the 2000/01 marketing year.

This production decline mirrors a fall in U.S. consumer demand and is not the result of competition from imports. U.S. per capita consumption of fresh grapefruit has declined from a high of 7.84 pounds per person in 1982/83 to 2.71 pounds per person in 2009/10. Several factors could be affecting demand for the fruit. First, unlike many other fruits, grapefruit is difficult to eat out of the hand, and consumer convenience has become an increasingly important driver of fruit demand over the past decade. Second, a wider array of imported fruits are now available during the winter months when grapefruit is typically marketed, so grapefruit has lost marketing share. Lastly, grapefruit consumption declined in the 1990's after several studies found that grapefruit amplified the effects of certain medications. Unfortunately, the same people most likely to be taking such medications were also one of

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[1] Most citrus imports (greater than 80 percent) enter the U.S. under duty-free status due to various trade agreements. For those countries who do not qualify for duty-free status, tariff rates are relatively consistent across products from 1.5¢ to 2.5¢ per kilo or 0.8% per kilo for Tahitian limes and "other citrus" categories. Although tariffs vary seasonally for grapefruit, more than 99% of grapefruit imports enter the U.S. under duty-free status. For these reasons, we do not believe that the tariff structure significantly alters our result.

the most important demographics of grapefruit consumers – people over the age of 50. This fear of interaction has likely been the most important driver of reduced domestic fresh grapefruit demand (Perez and Pollack, 2005).

With declining consumer demand, it is not surprising that imports of grapefruit are small, accounting for around 3 percent of U.S. fresh grapefruit consumption. Imports generally peak in the late fall and early winter when U.S. domestic shipments are also greatest. April and May are the lightest months for imported grapefruit. Most imports are sourced from Mexico and the Bahamas, both of which enjoy duty-free access under NAFTA and the Caribbean Basin Initiative, respectively.

Limes

As a share of consumption in the U.S., imports are most important for limes, now accounting for virtually 100 percent of the limes consumed in the U.S. Formerly, limes had been grown in Florida due to that State's sandy soils and sub-tropical climate: ideal conditions for lime production. However, the Florida industry suffered severe tree losses from Hurricane Andrew in 1992 – production declined nearly 80 percent between the 1992/93 and 1993/94 marketing years, with area declining to 1,900 acres from a high of 7,500 acres in the 1980's. Replanting was slow in the aftermath of Hurricane Andrew, and the industry was unable to fully recover before an epidemic of citrus canker affected groves in the main production areas of Southeastern Florida (Perez and Pollack, 2000). By 2002, less than 400 acres of commercial lime groves existed in Florida. Groves could not be replanted because of the continuing citrus canker threat, and with demand for vegetable crops and urban encroachment driving up the price of land, commercial lime production all but ceased in the 2002/03 crop year when the National Agricultural Statistics Service (NASS) discontinued its lime production survey (Perez and Pollack, January 2003a).

Even before Hurricane Andrew, imports were rising as a share of consumption, reaching nearly 80 percent of total consumption in 1992/93. However, after the hurricane, imports surged 30 percent and were able to provide adequate supplies for U.S. consumers (Kantor and Malanoski, 1997). Beginning in 1993/94, imports made up at least 90 percent of U.S. lime consumption and have been responsible for virtually 100 percent of U.S. lime consumption since the demise of the U.S. lime industry in 2002/03. Around 97 percent of U.S. lime imports come from Mexico. Similarly, over 90 percent of that country's lemon/lime exports are shipped to the U.S. For this reason, either a shock to Mexican lime production or to U.S. consumer demand would heavily influence U.S. lime import levels. Though limes are available year-round to consumers, imports tend to peak in the summer months of July and August, with the lightest demand experienced in January and February.

Per capita lime consumption continues to grow in the United States, more than doubling from 1.15 pounds per person in 1996/97 to 2.57 pounds per person in 2009/10. This increase is partially due to a rising Hispanic population, as limes are a key ingredient in many Latin cuisines. Due to their high acid content, limes are not typically directly consumed as an orange or grapefruit might be. Instead, their juice is used as a flavoring.

Lemons

Though lemons are similar to limes in that they are typically used as a flavoring agent and not directly consumed because of high acidity, production and import demand for the two crops are quite different. U.S. production of lemons remains strong, supplying more than 90 percent of domestic consumption needs and even making the U.S. the fifth-largest exporter of fresh lemons/limes in the world (USDA PS&D, 2011).

Nearly all U.S. lemons are produced in the States of California and Arizona. The U.S. lemon season runs from August through July, with Californian producers able to store production long enough to partially supply the high-demand summer season. Imports tend to be highest during the summer months. However, U.S. production is just gearing up for harvest at that time, and domestic supplies are at their lowest (Perez and Pollack, 2004). Despite rising import demand during the summer months, imports only account for around 10 percent of U.S. consumption.[2] Mexico and Chile are the primary sources of U.S. lemons imports, with both countries able to ship lemons duty-free through free trade agreements.

Though per capita fresh lemon consumption has fluctuated in recent years, it has generally been on an upward trend. U.S. lemon production and consumption are projected to continue increasing, with imports filling seasonal demand gaps.

Mandarins

As with lemons, the U.S. mandarin/tangerine industry is on a trend of both increasing production and consumption. Unlike lemons, however, imports make up a significant portion of U.S. mandarin consumption, and the fruits themselves are typically directly consumed. Worldwide, mandarins are known for being easy to peel and readily separating into different sections, which makes them convenient to eat in fresh form (Perez and Pollack, 2003b). Moreover, many different countries in the world produce their own particular varieties of mandarins, including satsumas, clementines, and numerous tangerine hybrids.

U.S. production of mandarins has more than doubled since 1992/93, reaching 960 million pounds in 2009/10. California produces nearly 65 percent of the U.S. mandarin crop, with Florida accounting

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[2] In fact, the U.S. exports twice as many lemons as it imports in a marketing year, though these shares differ on a seasonal basis.

for most of the remainder. Expansion has been driven by increasing consumer demand for the fruit, mostly due to its convenience. For this reason, mandarins have been able to successfully compete for a share of U.S. consumers' fresh food dollars, while oranges and grapefruit have not. Consequently, per capita consumption of mandarins has doubled since 1992/93.

While most mandarins consumed in the U.S. are domestically-grown, seasonal imports account for nearly 30 percent of consumption. Unlike other citrus varieties, mandarins do not store well on the tree and should be harvested soon after maturity. For this reason, the U.S. marketing season for mandarins is shorter than it is for other citrus varieties. Nearly half of U.S. mandarin imports come from Spain, with Chile, Morocco, and Peru accounting for most of the remainder. Imports from Spain are nearly all of the clementine variety, which are in high demand by U.S. consumers because they are seedless. Total U.S. imports tend to peak November through January when the bulk of Spain's crop is marketed. A smaller peak occurs in July and August when Chilean clementines and Peruvian tangelos enter the market.

Other citrus fruits

A few specialty citrus varietals – including citrons, kumquats, and bergamots – are also imported into the United States under a catchall "other citrus" tariff category. Though their quantities remain small (less than 460 tons of specialty "other citrus" were imported in 2010 compared to more than 140,000 tons of mandarins), they are included in this analysis because of their niche market appeal. Additionally, more than 80 percent of these "other citrus" imports are sourced from Jamaica. Simultaneously, 30 percent or more of Jamaica's total citrus exports to the U.S. are classified as "other," such that any identifiable trend in imports of this category could have significant implications for that nation.

Empirical Specification of the Almost Ideal Demand Model

In order to gain further insights into the demand for U.S. citrus imports, we chose to employ the nonlinear Almost Ideal Demand System (NAIDS) model as specified by Deaton and Muellbauer as:

$$w_i = \alpha_i + \sum_{i=1}^{k} \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{m}{P*}\right) \tag{1}$$

where w_i is the budget share of imported citrus i, p_j is the price of imported citrus j, m is the total expenditure on all imported citrus in the demand system, and $P*$ is the translog price index which is

defined as $\ln(P*) = \alpha_0 + \sum_{i=1}^{k} \alpha_k \ln(p_k) + 0.5 \sum_{i=1}^{j} \sum_{j=1}^{k} \gamma_{kj}^* \ln(p_k) \ln(p_j).$ \hfill (2)

α_i, β_i, and γ_{ij} are coefficients to be estimated and $\gamma_{ij} = (\gamma_{ij}^* + \gamma_{ji}^*)/2$.

Arnade and Pick (1998) extended their model to account for seasonal patterns using harmonic analysis. They used a variable consisting of an interaction term between a trend variable and a trigonomic variable representing a particular frequency, then used this variable to detect changes in the seasonal cycle. We extend the standard nonlinear AIDS model for import demand to incorporate seasonal and trend effects. The informational shift variables are incorporated into the α_i parameter as:

$$\alpha_i = \phi_i + \sum_{i=1}^{k} \varphi_i S + \lambda_i T_i \tag{3}$$

where S is the vector of seasonality, T is a trend variable, and $\alpha, \gamma, \beta, \phi$, and λ are parameters to be estimated. Utility maximization requires that the coefficients satisfy the following restrictions: adding up satisfied by $\sum_i \alpha_i = 1; \sum_i \gamma_{ij} = 0; \sum_i \beta_i = 0; \sum_i \phi_i = 1; \sum_i \varphi_i = 0; \sum_i \lambda_i = 0$; homogeneity is satisfied if

$\sum_j \gamma_{ij} = 0 \forall i$; and symmetry is satisfied if $\gamma_{ij} = \gamma_{ji} \forall i \neq j.$

Deviating from Arnade and Pick (1998), we follow Makridakis, Wheelwright, and McGee (1983), and

Washington, Kilmer, and Weldon (2002), where S is a nonlinear problem:

$$S = \sigma \sin\left[\left(\frac{f * t}{n}\right)2\pi + \zeta\right]$$
(4)

Where σ is the estimated amplitude of the sine wave, f is the frequency of completion of the sine wave

over the number of observations, t is the time, n is the number of observations, and ζ is the estimated

phase angle. Based on trigonometric theory, equation 4 can be linearized where

$$S_i = \sigma \cos\zeta \sin\left[\left(\frac{f * t}{n}\right)2\pi\right] + \sigma \sin\zeta \cos\left[\left(\frac{f * t}{n}\right)2\pi\right]$$
(5)

If σ cos ζ = s_1 and σ sin ζ = s_2, then

$$S = s_1 \sin\left[\left(\frac{f * t}{n}\right)2\pi\right] + s_2 \cos\left[\left(\frac{f * t}{n}\right)2\pi\right]$$
(6)

The adding up condition $\sum_i \varphi_i = 0$ can be rewritten as $\sum_i s_{1i} = 0$, and $\sum_i s_{2i} = 0$.

Following Makridakis, Wheelwright, and McGee (1983), we then calculate an average amplitude (σ)

and average phase shift (ç) as:

$$\sigma = \sqrt{s_1^2 + s_2^2}$$
(7)

and

$$\zeta = \arcsin\left[\frac{s_2}{\sqrt{s_1^2 + s_2^2}}\right]$$

(8)

There is often a concern for violating Closure Under Unit Scaling (or CUUS) when incorporating shift variables such as demographics into singular expenditure systems (Pollak and Wales, 1981; Lewbel, 1985). However, CUUS is maintained when the incorporated parameters do not depend on the data's scaling, especially the scaling of the data related to the shift variables themselves (Alston, Chalfant, and Piggott, 2001; Piggott and Marsh, 2004). In this case, the seasonal and trend variables are invariant to data scaling.

Parameters for equation 6 were estimated as part of the complete AIDS demand system where estimates of σ and ς are functions of the parameter estimates of s_1 and s_2. Because σ and ς are nonlinear functions of s_1 and s_2, the estimated standard errors of σ and ς give an indication of the significance of the average amplitude over time and phase shift, and therefore some aspect of the pattern of seasonality of citrus imports.

Utility maximization requires that the coefficients satisfy the following restrictions: Adding up is satisfied by $\sum_i \alpha_i = 1; \sum_i \gamma_{ij} = 0; \sum_i \beta_i = 0$; homogeneity is satisfied if $\forall_i \ \sum_j \gamma_{ij} = 0$; and symmetry is satisfied if $\gamma_{ij} = \gamma_{ji} \forall_{ij}$.

The price elasticities show the percentage changes in the quantity demanded associated with a one percent change in the price of imported commodity i. The expenditure elasticity from citrus fruit i shows the percentage change in the import expenditure of that good in response to a change in expenditure on all other imported citrus. Following Eales and Unnevehr (1993), the uncompensated price elasticity η_{ij}, expenditure elasticity η_i, and compensated price elasticity η_{ij}^* are calculated as:

$$\eta_{ij} = -\delta_{ij} + \frac{\{\gamma_{ij} + \beta_{ij}(w_j - \beta_j \ln(x/p))\}}{w_i} \tag{9}$$

$$n_i = -1 + \frac{\beta_i}{w_i} \tag{10}$$

$$\eta_{ij}^* = \eta_{ij} + w_j \eta_i \tag{11}$$

where δ_{ij} is the Kronecker delta that takes on the value of one if $i=j$ and zero otherwise.

Data

Quarterly import data from 1989:1 to 2010:4 is used in estimating the direct demand model. The data consist of U.S. citrus imports of 6 major commodities—oranges, grapefruit, mandarins, lemons, limes, and "other," which is an aggregate category for any remaining imported citrus commodities. Figure 1 summarizes U.S. citrus imports by commodity between 1989 and 2010. Limes account for the largest expenditure share of U.S. citrus imports.

Import quantities and expenditures for each commodity were obtained from the U.S. Department of Agriculture, Economic Research Service's *Data Access Retrieval and Tabling System,* which obtains its data from the U.S. Census Bureau. All expenditures are on a cost, insurance, and freight (CIF) basis. Using expenditures and quantities, per-unit values ($/lb) for each commodity were calculated. U.S. domestic citrus was excluded from the model for three reasons. First, the paper seeks to estimate U.S. import demand for a range of citrus commodities. Second, while there are expenditures and quantities from which a unit value (price proxy) could be derived, there is no clear way of obtaining the quantity of U.S. fresh citrus demanded. In addition, obtaining a composite domestic price for each citrus commodity may be difficult since the range of USDA-reported citrus prices is not associated with a

quantity. Last, a significant portion of domestic citrus is used primarily for the processing market, while imported citrus is used primarily in the fresh and flavoring markets.

Results

Various specification tests were done on the import demand equations outlined above. They included autocorrelation (Durbin-Watson and Godfrey tests), heteroskedasticity (White test) and a Wu-Hausman endogeneity test for endogeneity of the quantity variables. Test results did not indicate the presence of endogeneity of the quantity variables or the presence of autocorrelation or heteroskedasticity in the residuals. However, we corrected for autocorrelation using the approach specified by Moschini and Moro (1994) which allow for first-order autocorrelation within and across equations. This specification ensures invariance with the deleted equation and that the adding-up condition is maintained. Parameter estimates for the full model, which includes the seasonal and trend variables, are presented in Tables 1 and 2. Interestingly, although the trend estimates for oranges, grapefruit, and limes were significant, the magnitude of the trend was negligible. The seasonal (sine and cosine) coefficient does not provide an adequate interpretation of seasonality. As such, seasonality is explored later by examining the amplitude and phase shift of the different citrus fruits.

The compensated price and expenditure elasticities are presented in Table 3. The asymptotic standard errors are shown in parentheses. These elasticities are conditional on the total expenditure on all imported citrus. The expenditure elasticities were all positive and statistically significant except for "other citrus." Positive expenditure elasticities suggest normal goods. The estimated expenditure elasticities for oranges, grapefruit, mandarins and lemons were all greater than one (1.442, 1.479, 1.360, and 1.164, respectively) while limes and other citrus had expenditure elasticities of less than one (0.518 and 0.262, respectively). These findings suggest that as income increases, consumers would likely

spend a higher proportion of their overall imported citrus expenditure on oranges, grapefruit, mandarins and lemons and less on limes and other citrus.

The compensated price elasticities represent both the substitution and expenditure effect of price changes. Consistent with theory, all own-price elasticities had the correct negative sign and were statistically significant (except for oranges), implying that an increase in the import price of a citrus commodity reduces its quantity demanded. Grapefruit and other citrus were fairly price responsive with own-price elasticities greater than one in absolute value (elasticities of -1.136 and -1.405, respectively), such that it is not possible for the supplying countries of these two citrus commodities to increase revenue by lowering quantities supplies. Also, an increase in the price of imported grapefruit and other citrus would result in a more than proportional decrease in the quantity imported. However, based on the inelastic own-price elasticities for oranges, mandarins, lemons, and limes (-0.050, -0.359, -0.742, and -0.126), supplying countries could increase their revenues by lowering the quantity they supply to the United States, and an increase in the price of these imported commodities would result in a less than proportional decrease in the quantity imported.

The compensated cross-price elasticity relates to the quantity imported of a commodity when the price of another commodity changes, holding utility constant. The compensated cross-price elasticity determines substitutability and complementarity between products. These cross-price effects account for both the substitution and expenditure effects of price changes. Positive compensated cross-price elasticities indicate a substitute relationship between products while negative compensated cross-price elasticities indicate a complementary relationship and may suggest that the expenditure effect of the price change has outweighed the pure substitution effect. As expected, most of the cross-price elasticities for citrus fruits are positive, but only a few are statistically significant, implying that U.S. citrus imports are mostly substitutes across commodities, but perhaps only weak substitutes. Since

imported citrus fruits are destined primarily for the fresh market, there is significant competition between commodities. The substitute relationship across commodities would suggest that changes in import prices could influence the U.S. consumer's loyalty to most imported citrus commodities.

Interestingly, none of the citrus fruits were found to be statistically significant natural substitutes for fresh oranges. However, grapefruit exhibited a statistically significant complementary relationship with oranges. Grapefruit were also found to exhibit substitute relationships with mandarins and other citrus. The results also showed that U.S. consumers were willing to substitute mandarins for lemons, limes and grapefruit, although grapefruit were shown to exhibit the strongest substitute relationship with mandarins. Limes and lemons were found to exhibit a complementary relationship, but not a statistically significant one.

Aspects of seasonality were also explored and presented. Table 4 presents the seasonal patterns as estimated by the amplitude and phase shift estimates for imported citrus fruits. The phase shift estimates are measures of the extent to which each frequency component of one series leads or lags the other. A positive phase shift means that the cycle is shifted backwards (appears earlier in the series) and a negative phase shift means that the cycle is shifted forwards (appears later in the series). The amplitude is the measurement of the sine wave from one peak to another. It measures the average height of the sine wave over time. Larger amplitudes suggest greater seasonality.

All imported citrus fruits exhibited statistically significant average amplitudes (except other citrus) with grapefruit having the smallest magnitude (0.005) and limes having the largest magnitude (0.174). However, based on the overall small magnitude of the amplitudes, it would appear that seasonality in fresh citrus imports is becoming less pronounced. The small magnitude on the amplitude of grapefruit may be explained by the low absolute level of grapefruit imports as compared to other

citrus fruits, and by declining overall consumer demand for both domestically-produced and imported grapefruit. The larger amplitude on limes may be largely due to the fact that most imported limes come from Mexico. As such, variations in Mexico's lime production would result in large variations in U.S. lime availability.

The average phase shift has also shed some light into the patterns of seasonality of imported citrus. Oranges, grapefruit, and lemons showed no statistical differences in their pattern of seasonality in imports over time. However, mandarins and limes have seen statistically significant shifts in their seasonal cycles over time. Mandarins have seen a positive shift in its cycle, suggesting that the seasonal cycle is occurring at earlier months over time. Limes, on the other hand, have seen a negative shift in its cycle, suggesting that peak imports are occurring at later months of the year. The decline in U.S. lime production likely precipitated the phase shift in U.S. lime imports.

Conclusions

Imported fresh citrus fruit continue to grow as a share of total U.S. citrus fruit consumption. This has sparked interest in understanding citrus import demand issues, as well as issues of seasonality. The previous research on U.S. fresh citrus fruits has been sparse and has not addressed the import demand dynamics of this sector, particularly seasonality.

The present analysis uses an AIDS demand model to explore U.S. import demand characteristics for all major categories of fresh citrus. The results suggest wide variations in import quantities in response to changes in prices for imported citrus. The expenditure elasticities of all the imported citrus commodities were positive, indicating that all the commodities are normal goods, consumption of which will increase with increased overall imported citrus expenditure. Additionally, various fruits exhibited

complementary or substitute relationships – grapefruits and other citrus were shown to be substitutes, while lemons and limes exhibited a complementary relationship.

The average amplitude and phase shift suggest that all citrus fruits exhibit some seasonality in their imports, likely a result of the peak harvesting schedules of principal citrus fruit exporters. The degree of the amplitude illuminated the importance of diversification in sourcing fresh citrus fruits, if demand is to remain steady and continuous. Fresh citrus fruits that were sourced from fewer locations exhibited greater seasonal amplitude than fruits that were sourced from multiple global locations. The phase shift in imports provides some insight into the dynamics of the complementary domestic citrus industry. In the case of mandarins, its acceptance into the regular mainstream fresh fruit diet has tended to shift its consumption from being a one season product, while the phase shift in limes reflects the decline and eventual loss of the U.S. lime sector.

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Table 1. Nonlinear Almost Ideal Demand System Parameter Estimates for Imported Citrus

	Intercept	Orange	Grapefruit	Mandarin	Lemon	Lime	Other	Expenditure
Orange	-1.187** (0.487)	0.023 (0.096)	-0.021*** (0.007)	-0.216*** (0.049)	-0.006 (0.028)	0.212 (0.127)	-0.008 (0.012)	-0.083*** (0.029)
Grapefruit	-0.060 (0.068)		-0.002 (0.002)	0.003 (0.008)	0.001 (0.003)	0.015 (0.015)	0.003*** (0.001)	-0.005 (0.004)
Mandarin	-1.653*** (0.439)			-0.122 (0.101)	0.013 (0.030)	0.331*** (0.105)	0.017 (0.013)	0.113*** (0.006)
Lemon	0.108 (0.261)				0.011 (0.005)	0.004 (0.056)	0.004 (0.004)	-0.009 (0.016)
Lime	3.873*** (0.386)					-0.534*** (0.159)	-0.028* (0.022)	-0.203*** (0.023)
Other	0.135 (0.106)						-0.005** (0.002)	-0.007 (0.006)

Asymptotic standard errors are in parentheses.

***Significance level < 0.01
**Significance level < 0.05
*Significance level < 0.10

Table 2. Seasonality and Trend Estimates of Imported Citrus

	Cosine	Sine	Trend
Orange	-0.097***	-0.100***	-0.002**
	(0.020)	(0.024)	(0.001)
Grapefruit	-0.002	0.004	0.000***
	(0.003)	(0.003)	(0.000)
Mandarin	0.241***	0.144***	0.001
	(0.018)	(0.012)	(0.001)
Lemon	0.025**	-0.044***	0.000
	(0.010)	(0.010)	(0.000)
Lime	-0.121***	0.004	0.003***
	(0.018)	(0.021)	(0.001)
Other	0.003	0.001	0.0001
	(0.004)	(0.004)	(0.000)

Asymptotic standard errors are in parentheses.

***Significance level < 0.01

**Significance level < 0.05

Table 3. Compensated Nonlinear Almost Ideal Demand System Elasticities for Imported Citrus

	Orange	Grapefruit	Mandarin	Lemon	Lime	Other
Orange	**-0.050**	-0.059***	0.036	0.097	-0.022	-0.001
	(0.178)	(0.019)	(0.132)	(0.070)	(0.138)	(0.028)
Grapefruit	-1.011***	**-1.136*****	1.577***	0.251	0.064	0.256***
	(0.329)	**(0.144)**	(0.300)	(0.214)	(0.310)	(0.093)
Mandarin	0.021	0.055***	**-0.359*****	0.075*	0.189***	0.018
	(0.079)	(0.011)	**(0.096)**	(0.043)	(0.067)	(0.015)
Lemon	0.316	0.048	0.411*	**-0.742*****	-0.088	0.055
	(0.228)	(0.041)	(0.233)	**(0.175)**	(0.209)	(0.011)
Lime	-0.010	0.002	0.141***	-0.012	**-0.126***	0.006
	(0.061)	(0.008)	(0.050)	(0.028)	**(0.070)**	(0.012)
Other citrus	-0.025	0.285***	0.583	0.322	0.237	**-1.405*****
	(0.545)	(0.104)	(0.481)	(0.301)	(0.496)	**(0.177)**
Expenditure Elasticity	1.442**	1.479***	1.360***	1.164***	0.518***	0.262
	(0.157)	(0.372)	(0.084)	(0.275)	(0.055)	(0.655)
R2	**80.20**	**58.02**	**92.49**	**68.76**	**91.60**	**34.56**
DW	**1.711**	**1.933**	**1.906**	**2.150**	**2.041**	**1.815**

Asymptotic standard errors are in parentheses.

***Significance level < 0.01
**Significance level < 0.05
*Significance level < 0.10

Table 4. Amplitude and Phase Shift in Seasonal Citrus Imports by the United States.

	Amplitude	Phase shift
Orange	0.092***	0.282
	(0.015)	(0.195)
Grapefruit	0.005**	-0.733
	(0.002)	(0.583)
Mandarin	0.111***	1.464***
	(0.018)	(0.104)
Lemon	0.021***	0.307
	(0.007)	(0.414)
Lime	0.174***	-1.009***
	(0.018)	(0.122)
Other citrus	0.003	1.412
	(0.004)	(1.292)

Asymptotic standard errors are in parentheses.

***Significance level < 0.01

**Significance level < 0.05
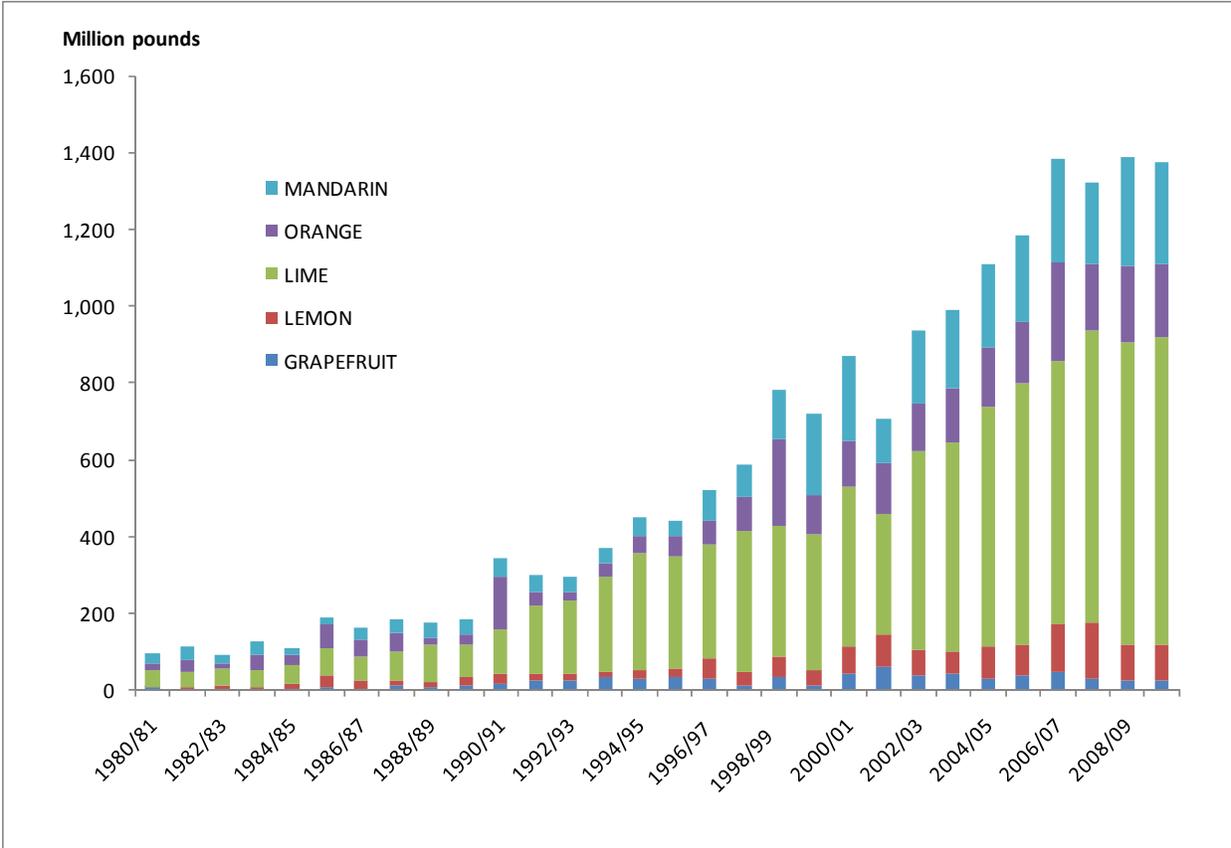
Figure 1 – While total U.S. citrus imports are increasing, trends vary by commodity

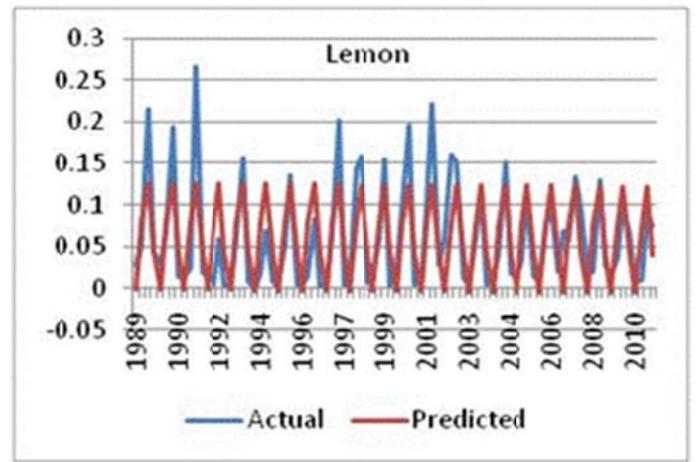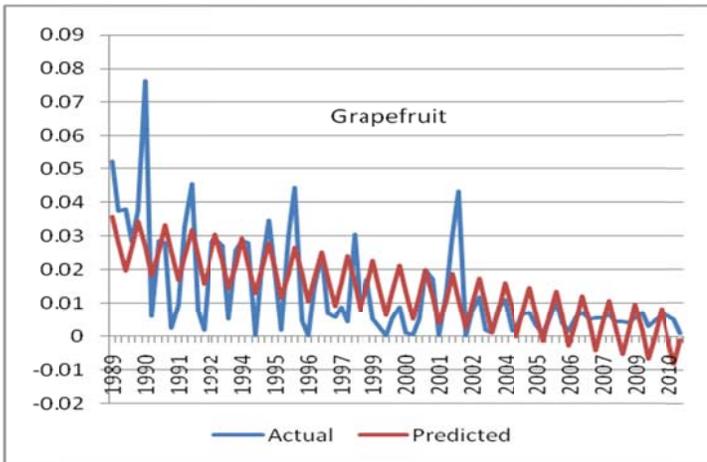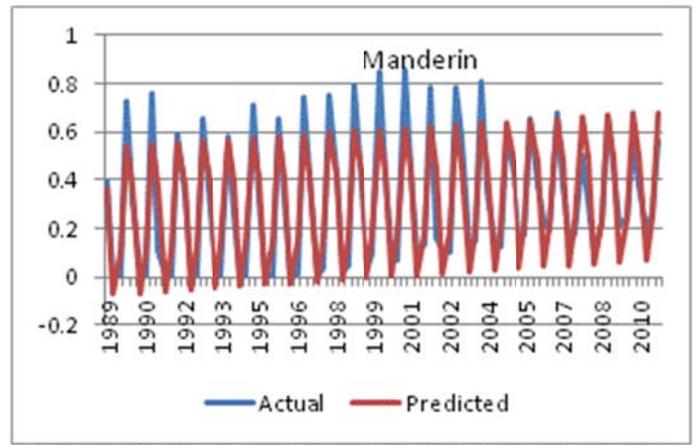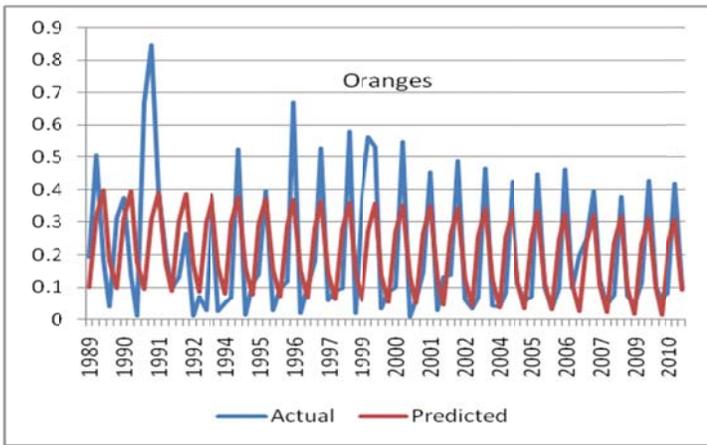Source: USDA, Economic Research Service, 2010b.
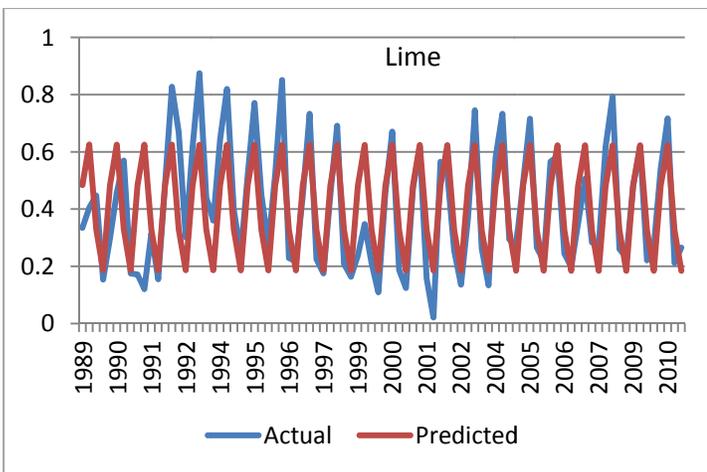
Figure 2. Seasonality associated with citrus imports by
the United States