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SUBSTITUTION BETWEEN DOMESTIC AND IMPORTED ORANGE JUICE AND IMPACTS OF U.S. TARIFFS ON PRICES AND PRODUCTION

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Abstract

A demand system model differentiating goods by product form and origin is developed to examine the impact of eliminating U.S. tariffs on orange-juice prices. An empirical analysis suggests a range of tariff impacts on prices depending on the degree of substitution between products. The model yielded similar results as alternative models when substitution was assumed to be relatively strong. In the long run, lower, without-tariff prices can be expected to lead to lower Florida orange planting and production levels. A sustained reduction in the U.S. OJ price of half the value of the FCOJ tariff is estimated to reduce orange planting levels by about 50% and orange production would decline by 24% by 2021-22.

Key word: prices, tariffs, orange juice, product differentiation.

Substitution Between Domestic and Imported Orange Juice and Impacts of U.S. Tariffs on Prices and Production

Most U.S. imports of orange juice (OJ) are subject to a tariff. For 2001, the most favored nation (MFN) tariff rates for frozen concentrate orange juice (FCOJ) and not-from-concentrate orange juice (NFC) are \$.289 per pounds solids (PS) and \$.166/PS, respectively. The MFN tariff rates have declined by 15% since 1994 according to the General Agreement on Trade and Tariffs (GATT). No further tariff rate declines are scheduled, but with the trend towards trade liberalization including special trade agreements between blocks of countries, uncertainty exists with regard to what future tariff rates may be. The MFN tariffs apply to Brazil which is the largest producer of OJ in the world and is the dominant supplier of imported OJ to the U.S. market. U.S. OJ imports from Carribean countries, Andean Trade Preference Act countries, Israel and Canada are duty free. OJ imports from Mexico receive preferential treatment as established by the North American Free Trade Agreement (NAFTA) — imports from Mexico are subject to a reduced tariff rate for the first 40 million single-strength-equivalent (SSE) gallons of FCOJ and the first 4 million gallons of NFC; presently imports of FCOJ above the 40 million gallon quota level are subject to a tariff rate that is about the same as the MFN tariff; the NAFTA tariffs on FCOJ and NFC are scheduled to decline to zero by 2008.

This paper examines some potential impacts of removing these tariffs on OJ prices and orange production. Previous studies of the world OJ market have been based on various assumptions on differentiation of OJ products by origin and form. McClain analyzed the case where all OJ regardless of form and origin is a perfect substitute (Appendix A), while, in an analysis of the impact of the OJ tariff by Spreen et al, OJ is assumed to be differentiated by form but not origin (Appendix B). In this paper, we consider the case where OJ is differentiated by both origin and product form[1].

Our analysis focuses on U.S. OJ prices and Florida OJ production[2]. The supply and demand for Florida and Brazil OJ underlies the analysis. Brazil is the largest producer of oranges and OJ in the world, followed by the U.S., and Florida is the dominant producer of OJ in the U.S. In 1999-00, the U.S. and Brazil accounted for 86% of the oranges processed in the world (Food and Agricultural Organization of the United Nations), and Florida accounted for 95% of the OJ produced in the U.S.(Florida Department of Citrus, 2001a).

We begin by considering short-run price impacts with supply fixed, followed by a long-run analysis of Florida orange production under alternative scenarios reflecting potential impacts of the tariffs on prices and orange tree planting levels.

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[1] Armington proposed similar product differentiation in a study of international trade flows.

[2] See Spreen et al. for an analysis of the impact of U.S. OJ tariffs on world OJ production, demand and price, by market.

Substitute Demand System Model

Consider the demands for OJ by origin, focusing on two origins, the U.S. and the rest of the world (RW) for simplicity. The demand for each origin is an aggregate of demands across markets and OJ product forms. Formally, these demand can be written as

(1a) $q_1 = \alpha_1 + \beta_{11} p_1 + \beta_{12} p_2$

(1b) $q_2 = \alpha_2 + \beta_{21} p_1 + \beta_{22} p_2$,

or, in matrix form,

(1c) $q = \alpha + \beta p$

where q_s and p_s are the quantity and grower price of OJ produced in region s (s=1 for the U.S. and s=2 for the RW); α_s and β_{sj} are parameters; and $q = (q_1, q_2)'$, $p = (p_1, p_2)'$ and $\alpha = (\alpha_1, \alpha_2)'$ are 2x1 column vectors, and $\beta = (\beta_{11}, \beta_{12} / \beta_{21}, \beta_{22})$ is a 2x2 matrix. The parameters β_{11} and β_{22} are expected to be negative, based on the law of demand, and β_{12} and β_{21} are expected to be positive, given OJ from the U.S. and the RW are (imperfect) substitutes.

The intercepts (α_s) are of particular interest in the present study. A model specification that makes these parameters dependent on the U.S. and other country tariff levels is considered below.[3] In this model, a reduction in the U.S. tariff reduces the demand for U.S. OJ by decreasing the value of α_1 and increases the demand for OJ from the RW by increasing the value of α_2. With fixed supplies, changes in the α's would then have impacts on prices, i.e., inverting (1c), we have

(2a) $p = \beta^{-1} (q - \alpha)$

or

(2b) $p = \gamma + \pi q$,

where $\gamma = -\beta^{-1} \alpha$ and $\pi = -\beta^{-1}$. A change in the U.S. tariff would result in a change in γ which would then result in a change in p. If we can determine how α changes and have estimates of π, then we can estimate the impact of the tariff on prices. Below, we consider this problem, starting with the market specific, product-form demand specifications underlying (1c). The closely related OJ products in a market are similar to uniform substitutes (Theil), and we refer to the system of demand equations as a substitute demand system model.

We begin with the demands for four substitute OJ products sold in the U.S. and the RW. The

[3] From an econometric viewpoint, equation (1c) and subsequent equation (2b) are specified as varying coefficients specifications.

products are differentiated by type of OJ (FCOJ and NFC) and origin (U.S. and RW), that is, (a) FCOJ produced from U.S. oranges, (b) NFC produced from U.S. oranges, (c) FCOJ produced from RW oranges, and (d) NFC produced from RW oranges. The FCOJ category includes retail packaged FCOJ and reconstituted FCOJ product (RECON). Product quality tends to differ by product form and origin. Pasteurized NFC, the dominant type of this product form, is closer to fresh squeezed product than RECON, but both are convenient, ready-to-serve product forms, as opposed to retail packaged FCOJ which must be reconstituted by the consumer.

Let q^r_{si} be the quantity demanded in market r of OJ from supply region s of product form i. In specifying the demand for a good in the substitute demand system, we use two subscripts, one to indicate origin (s) and one to indicate product form (i), which is in contrast to the usual practice of denoting different goods in demand equations by one subscript. Also, let p^r_{jk} be the retail price in market r for product form k (k and i are used interchangeably) from supplier j (j and s are used interchangeably). We denote the delivered-in or grower price of OJ in supply region j by p_j and the margin between the retail price p^r_{jk} and p_j by c^r_{jk}. That is, $p^r_{jk} = p_j + c^r_{jk}$ — this specification is based on the assumptions that the delivered-in price for OJ in the U.S. is the same for FCOJ and NFC sold in the U.S. or the RW, and that delivered-in price for OJ in the RW (Brazil) is the same for FCOJ and NFC delivered to the U.S. or the RW.

With this notation, the demand in market r for product form i from supplier s can be written

$$\text{(3a)} \quad q^r_{si} = \alpha^r_{si} + \textstyle\sum_j \sum_k \beta^r_{si,jk}\, p^r_{jk}$$

or

$$\text{(3b)} \quad q^r_{si} = \alpha^r_{si} + \textstyle\sum_j \sum_k \beta^r_{si,jk}(p_j + c^r_{jk})$$

or

$$\text{(3c)} \quad q^r_{si} = \alpha^{*r}_{si} + \textstyle\sum_j \sum_k \beta^r_{si,jk}\, p_j$$

where α^r_{si} is an intercept for demand in market r for the differentiated product defined by supply region s and product form i (the α's include the effects of income and other non-price variables); the β's are quantity-price slopes for the different demands, i.e., $\beta^r_{si,jk} = \partial q^r_{si} / \partial p^r_{jk}$, indicating the change in the quantity demanded of q^r_{si} for a change in the price of p^r_{jk} (the s and i subscripts on $\beta^r_{si,jk}$ indicate the product demanded and the j and k subscripts indicate the price of the product impacting this demand); and $\alpha^{*r}_{si} = \alpha^r_{si} + \sum_j \sum_k \beta^r_{si,jk}\, c^r_{jk}$, which can be viewed as a transfer-cost conditional intercept. The parameter α^{*r}_{si} is the varying parameter specification we are looking for in context of equations (1a) through (2b). We will be considering how changes in the margins due to changes in tariffs affect the intercepts α^{*r}_{si}, and, in turn, prices (p_j)[4]. We assume $q^r_{si} > 0$ (i.e., no corner

[4] This analysis is based on the assumption that the tariff is a fixed amount per unit of product (excise tax), which is the case for U.S. tariffs on OJ, but is not the case for ad valorem

solutions), and symmetry of cross-price effects ($\beta^r_{si,jk} = \beta^r_{jk,si}$) is not required, as opposed to in the general spatial equilibrium problem (Appendix B).

As shown in Appendix C, equations (3a) through (3c), underlying the substitute demand system model, can alternatively be motivated using the spatial equilibrium model suggested by Takayama and Judge.

To solve for the impact of the tariff on prices, sum equation (3b) over markets (r) and product form (i), finding that the quantity demanded of OJ from region s can be written as

$$(4) \qquad q_s = \textstyle\sum_r\sum_i \alpha^r_{si} + \sum_j\sum_r\sum_i\sum_k \beta^r_{si,jk}(c^r_{jk}) + \sum_j\sum_r\sum_i\sum_k \beta^r_{si,jk}(p_j).$$

Equation (4) is the same as (1a) and (1b) with $\alpha_s = \sum_r\sum_i \alpha^r_{si} + \sum_j\sum_r\sum_i\sum_k \beta^r_{si,jk}(c^r_{jk})$ and $\beta_{sj} = \sum_r\sum_i\sum_k \beta^r_{si,jk}$. The disaggregation of α_s allows analysis of tariff changes.

Totally differentiating result (4), find

$$(5) \qquad dq_s = \textstyle\sum_j\sum_r\sum_i\sum_k \beta^r_{si,jk}\, dc^r_{jk} + \sum_j \beta_{sj}\, dp_j.$$

The first term on the right hand side of equation (5) shows the change in the intercept for demand for OJ from supply region s due to changes in the grower-retail price margins.

In the short run, the supply from region s is constant, and, given the supply equals the demand for product from this region, q_s is constant in equation (4) and $dq_s = 0$ in equation (5). Also, changes in "only" U.S. tariffs imply $dc^r_{jk} = 0$, except for dc^1_{21} and dc^1_{22} (the tariff-related margin changes for FCOJ and NFC originating from the RW and sold in the U.S.). Hence, in the short-run when only the U.S. tariff changes, equation (5) can be written as

$$(6) \qquad 0 = \textstyle\sum_k \sum_i \beta^1_{si,2k}\, dc^1_{2k} + \sum_j \beta_{sj}\, dp_j.$$

Define the 2x2 matrix $\beta_c = [\sum_i \beta^1_{1i,21}, \sum_i \beta^1_{1i,22} / \sum_i \beta^1_{2i,21}, \sum_i \beta^1_{2i,22}]$; and the 1x2 vectors $dp = [dp_1, dp_2]'$ and $dc = [dc^1_{21}, dc^1_{22}]'$. Hence, in context of equations (1a) through (2c), result (6) can be written as

$$(7) \qquad \beta\, dp = -\beta_c\, dc$$

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tariffs on OJ in Europe. The latter tariffs are 15.2% of the European landed value of OJ. Ad valorem tariffs can be included in equation (3a) by defining the price p^r_{jk} as $\lambda^r_i (p_j + c^r_{0jk}) + c^r_{1jk}$ where c^r_{0jk} is the cost of transporting the product to the importing country and c^r_{1jk} is the cost margin between the retail and import levels. In context to equation (3c), an ad valorem tariff changes both the quantity-price slope and intercept.

or, solving for dp,

(8) $dp = -\beta^{-1} \beta_c \, dc$

or

(9) $dp = -\pi \, \beta_c \, dc$.

Result (9) for differentiated products is an extension of results (A3) and (A4) in Appendix A for the case where all OJ products are perfect substitutes—a single price slope in the perfect substitute model versus own and cross-price slopes in result (9). The cross- price demand slopes ($\beta^r_{si,jk}$, $s \neq j$ and $i \neq k$) are expected to be positive to the extent that the different products are substitutes, while own-price demand slopes($\beta^r_{si,jk}$,$s=j$ and $i=k$) are expected to be negative.

The tariff-induced- intercept-changes ($\beta_c dc$) indicate how the demand for OJ from a specific origin changes. The two elements of dc are negative for elimination of the U.S. tariffs, i.e., dc = (-$.30/gallon, -$.17/gallon) or, in terms of pound solids, dc = (-$.289/PS, -$.166/PS). The corresponding two elements in the first row of β_c are each expected to be positive as each is a sum of cross-price demand slopes for substitute products. Hence, the first element of $\beta_c dc$ is expected to be negative, i.e., demand for U.S. OJ decreases. On the other hand, the two elements in the second row of β_c are each expected to be negative as each is a demand-slope sum including a presumably dominant negative own-price slope. Hence, the second element of $\beta_c dc$ is expected to be positive, i.e., the demand for RW OJ increases. All the elements of $-\pi$ are expected to be positive, assuming substitute relationships (π is the matrix of inverse demand slopes and an increase in own or substitute product supplies are expected to decrease prices). Hence, signing the elements of $dp = -\pi \ \beta_c dc$ is less straightforward—the first element is expected to be negative, while the second is expected to be positive (the U.S. price decreases and the RW price increases), but this result is not guaranteed. This ambiguity can also be seen by defining $dq^* = -\beta_c dc$ as a "notional quantity"(the negative of the change in quantity demanded as a result of elimination of the tariffs with constant prices p), so that $dp = \pi \ dq^*$. The U.S. and RW elements of dq^* are positive and negative, respectively, making the price changes unclear.

Empirical Analysis of Impact of U.S. Tariff on Price

Empirically, application of (9) may be difficult because it requires all own-price and cross-price slopes for the various products by form, origin, and market. For the world OJ situation, data are not available to estimate all of these price slopes. Data for Florida and Brazil, however, are available and were used to do a partial analysis of the impact of eliminating the U.S. tariff on the U.S. price; the data are not complete to make a good estimate of the impact on the RW price.

Our first step is to estimate the price-quantity slopes for the first equation in model (2b).

We regressed the Florida grower price on Florida and Brazil OJ movement levels and time (a proxy for growth factors). Annual data from the 1980-81 season through 1999-00 season were used. The Florida grower price is the packing-house-door price reported by the National Agricultural Statistical Service (NASS)—the NASS price in dollars per box was translated to dollars per single strength equivalent (SSE) gallon using Florida Citrus Processor Association (FCPA) juice yields. The quantity of Florida OJ in world markets was estimated as beginning minus ending Florida OJ inventory plus Florida OJ production (FCPA)[5]. Similarly, the quantity of Brazil OJ in world markets was estimated as beginning minus ending Brazil OJ inventory plus Brazil OJ production (USDA, Brazil Attache). The estimated equation is

$$(10) \quad \underset{(.291)}{p_1 = 2.447} \; \underset{(.023)}{- 0.108\, q_1} \; \underset{(.036)}{- 0.078\, q_2} \; \underset{(.026)}{+ 0.065\, t}$$

where the numbers in parentheses under the estimated coefficients are estimated coefficient standard errors. The R-square was .71 and the Durbin-Watson value was 1.72. The quantities are measured in 100 million gallons, and hence a 100 million gallon increase in Florida (Brazil) OJ supply decreases the Florida price by about \$.108/gallon (\$.078/gallon).

The next step is to estimate the demand slopes embedded in the (1x2 dimension) vector

$$(11) \quad \beta_c dc = -(.30\textstyle\sum_i \beta^1_{1i,21} + .17\sum_i \beta^1_{1i,22}\, ,\, .30\sum_i \beta^1_{2i,21} + .17\sum_i \beta^1_{2i,22})'.$$

Little NFC is imported so we will ignore this component in the present analysis (i.e., $\sum_i \beta^1_{1i,22} = \sum_i \beta^1_{2i,22} = \beta^1_{22,21} = 0$), although in the future this situation may change and the general result which allows for impacts through foreign NFC may become important. Therefore, result (11) can be written as,

$$(12) \quad \beta_c dc = -.30(\textstyle\sum_i \beta^1_{1i,21}\, ,\, \beta^1_{21,21})'.$$

Equations (11) and (12) are the negative of "notional quantity."

Thus, we need to obtain estimates of how the demands in the U.S. market for Florida FCOJ, Florida NFC and Brazil FCOJ change with respect to a change in the Brazil FCOJ price. U.S. demand elasticity estimates are for aggregate Florida and Brazil OJ products. We estimate the U.S. retail market own-price elasticities of demand, ($e^1_{1i,1i} = \partial q^1_{1i} / \partial p^1_{1i})(p^1_{1i} / q^1_{1i}$), for FCOJ/RECON (i=1) and NFC (i=2) as -.7 and -1.1, based on results reported by Brown and Lee[6]. These elasticities

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[5] Florida OJ inventories are comprised of Florida and imported product, but a breakdown between these two products was not available, and inventory changes are assumed to be largely Florida product, given Florida imports are relatively minor compared to Florida OJ production.

[6] Compensated elasticities at sample means are used, as opposed to elasticities at the end of the sample due to uncertainty with respect to disaggregating income an trend effects.

are translated into slopes (β's) by multiplying $e^1_{1i,1i}$ times (q^1_{1i}/p^1_{1i}).

In 2001-02, Florida FCOJ/RECON and NFC movement levels to the U.S. market are estimated at 915 and 565 million gallons, respectively (based on FCPA data); and U.S. retail FCOJ/RECON and NFC prices are estimated at $3.78/gallon and $5.28/gallon, respectively(based on ACNielsen data). Hence, for Florida FCOJ/RECON and NFC sold in the U.S. market, the estimated own-price slopes ($\beta^1_{11,11}$ and $\beta^1_{12,12}$) are -169 and -118 million gallons per dollar, respectively (-.7*915/3.78; -1.1*565/5.28). In the last five seasons ending in1999-00, annual U.S. OJ imports from Brazil have averaged 203 million gallons, and the own-price slope for Brazil FCOJ/RECON ($\beta^1_{21,21}$) is estimated at -38 million gallons per dollar (-.7*203/3.78) for Brazil FCOJ in the U.S. market. Estimates of the cross-price slopes for the U.S. FCOJ and NFC demand equations with respect to the price of Brazil FCOJ($\beta^1_{11,21}$, $\beta^1_{12,21}$) are unknown, but, given all cross-price elasticities are expected to be positive and the homogeneity condition of demand which requires the sum of own-price and cross-price compensated elasticities for a good to be zero[7] (e.g., $e^1_{1i,11} + e^1_{1i,12} + e^1_{1i,21} = 0$), maximum values for these cross-price slopes were estimated as $e^1_{11,21} = -e^1_{11,11}$ and $e^1_{12,21} = -e^1_{12,12}$. For the U.S. FCOJ demand equation, the maximum cross-price slope with respect to the Brazil FCOJ price ($\beta^1_{11,21}$) is estimated at 169; likewise, for the U.S. NFC demand equation the value of the maximum cross-price slope with respect to Brazil FCOJ is estimated at 164 ($\beta^1_{12,21}$ =1.1*565/3.78). Hence, an upper estimate of the impact of the U.S. tariff is dp_1 = -$.10/gallon — .30 (-0.108 (169+164) + -0.078 (-38))/100). If the assumed cross-price slopes are smaller, say because of substitution between U.S. FCOJ and U.S. NFC ($\beta^1_{11,12} >0$, $\beta^1_{12,11} >0$), the impact of the tariff on price would be smaller.

How sensitive is the impact of the tariff on price to the underlying demand parameter estimates? Some examples are provided to try to answer this question. We focus on how large the tariff impact on price might be based on statistical variation of our estimates. There are two sources of error in the foregoing analysis—1) the inverse demand slopes and 2) the direct demand slopes for the U.S. For inverse demand equation (10), the 95% confident interval for the coefficient estimate on q_1 is - 0.108 ± .023*2.11, which includes the extreme value of -0.157. This extreme coefficient value for q_1 along with a coefficient value of -.038 for q_2 fall in the 95% confident interval for these two coefficients, based on the F distribution. Using these two values, the estimated tariff impact is dp_1 = -$.15/gallon — .30 (- 0.157*(169+164) + - 0.038(-38)/100). Likewise, largest reported own-price elasticity estimate for NFC[8] was -1.6 (the FCOJ/RECON own-price elasticity varied little). Using this elasticity estimate along with the extreme values for the inverse demand equation, the estimated impact of the tariff on price is -$.19/gallon. Alternatively, focusing on how small the impact might be, we can not rule out the possibility that the impact on price may be virtually zero ($\beta^1_{11,21} = \beta^1_{12,21} = 0$, and low price flexibility estimates), although we doubt this is the case. It is more likely that all the cross-price slopes are greater than zero ($\beta^1_{11,12}$, $\beta^1_{11,21}$, $\beta^1_{12,11}$, $\beta^1_{12,21} >0$), and the

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[7] Proportionate increases in all prices, real income constant, leaves demand unchanged; see, e.g., Deaton and Muellbauer.

[8] Estimated by Brown and Lee at the beginning of the sample.

short-run impact of the tariff on price is some positive value less than -$.19/gallon[9].

This analysis suggests caution in making estimates of the impact of the U.S. tariff on the U.S. price. Due to data limitations, precise point estimates of the impact can not be made. The results, however, do not rule out the uniform substitute model and Spreen's spatial equilibrium model estimates that elimination of the tariff would reduce the U.S. price by somewhat more than half the tariff level. Some long-run production scenarios for this impact are examined below.

Long-Run Impacts

The long-run impacts of reducing or eliminating the U.S. tariffs on OJ are more difficult to predict, but the short-run impact of a lower price in the U.S. and, perhaps, a higher price in the RW (Appendix A) would tend to result in contraction of production in the U.S. and expansion of production in the RW, to the extent that the U.S. and the RW long-run supply functions are positively related to price.

To determine the long-run impacts of the tariff on Florida production, we first estimated relationships between Florida orange tree planting levels and on-tree prices (elimination of the tariff would be expected to lower the Florida OJ price which in turn would be expected to result in lower on-tree prices, lower orange tree planting levels and eventually lower Florida orange production). Separate planting relationships for early and midseason oranges and Valencia oranges were estimated. Planting levels were related to expected on-tree price variables for oranges and grapefruit[10]. Data on planting levels and on-tree prices were obtained from two publications by the

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[9] The impact of the tariff on price would not be expected to as large as the impacts of the freeze-related supply shifts in the past two decades. The 1x2 "notional quantity" vector ($dq^* = -\beta_c\, dc$) for the above estimates indicates $dq^*_1 = 100$ to 122, depending on the elasticity estimate assumed, and $dq^*_2 = -11$. That is, elimination of the U.S. tariff would be equivalent to a 100 to 122 million gallon increase in the supply of Florida OJ, along with a decrease in the supply of Brazil OJ by about 11 million gallons, all else constant. In contrast, the supply shifts in Florida over the last two decades have been substantially larger. As result of freeze reduced supplies, Florida OJ movement averaged 727 million gallons over the five-year period ending with the 1989-90 season. Over the next five-years ending in 1994-95, Florida movement averaged 983 million gallons, an increase of 257 million gallons; and over the five-years ending in 1999-00, Florida movement averaged 1292 million gallons, a further increase of 308 million gallons. Similar increases in Brazil OJ supplies and movement occurred over these periods.

[10] The prime interest rate and the interest rate for long-term U.S. government securities, proxies for alternative non-citrus investment opportunities, were also considered as explanatory variables but were found to be statistically insignificant.

Florida Agricultural Statistics Service. Annual data from 1965 through 1999 (35 observations) were studied.

Florida Orange Tree Planting Model

A double log model was used to analyze tree planting levels. Formally, the model can be written as

(13) $n_{it} = \delta_0 + \delta_1\, op^*_{1,t+1} + \delta_2\, op^*_{2,t+1} + \delta_3\, op^*_{3,t+1}$,

where subscript t stands for time (year); subscript i stands for variety of citrus (i=1 for early and midseason oranges; i=2 for Valencia oranges); n_{it} is the log of the number of trees planted of variety i in period t; and op^*_{jt} is the log of the expected on-tree price of variety j (j=1 for early and midseason oranges; j=2 for Valencia oranges, j=3 for grapefruit) in period t.

An adaptive expectations specification was used to model prices. The log of the expected on-tree price for each variety of citrus in the upcoming period is specified as a weighted average of the log of the current (actual) on-tree price and the log of current expected on-tree price. The weight for the log of the current price is λ ($0<\lambda<1$) and the weight for the log of the current expected price is $1-\lambda$. Formally, the expected price variables can be written as

(14) $op^*_{i,t+1} = \lambda\, op_{it} + (1-\lambda)\, op^*_{it}$

or, by recursively substituting for op^*_{it} in equation (14),

(15) $op^*_{i,t+1} = \sum_{j=0 \text{ to } t-1} \lambda(1-\lambda)^j\, op_{i,t-j} + (1-\lambda)^t\, op^*_{i1}$, i=1, 2,

where op_{it} is the log of the on-tree price of citrus variety i in year t; and op^*_{i1} is the log of the expected price for the first sample observation (1965). That is, the log of the expected price $op^*_{i,t+1}$ is composed of 1) the log of the expected price at the beginning of the sample op^*_{i1} times the factor $(1-\lambda)^t$ which decreases geometrically with time, and 2) a sum of weighted prices, $\sum_{j=0 \text{ to } t-1} \lambda(1-\lambda)^j\, op_{i\,t-j}$, in which the weights $\lambda(1-\lambda)^j$ decline geometrically over time,. The weight λ was selected so as to minimize the sum of squared errors.

Substituting expression (15) into equation (13) results in

(16) $n_{it} = \delta_0 + \delta_1 (\sum_{j=0 \text{ to } t-1} \lambda(1-\lambda)^j\, op_{1,t-j}) + \delta_2 (\sum_{j=0 \text{ to } t-1} \lambda(1-\lambda)^j\, op_{2,t-j}) +$
$\delta_3 (\sum_{j=0 \text{ to } t-1} \lambda(1-\lambda)^j\, op_{3,t-j}) + \delta_4 (1-\lambda)^t$

where $\delta_4 = op^*_{11} + op^*_{21} + op^*_{31}$.

Estimation of Planting Model

Preliminary analysis revealed a multicollinearity problem between the price variables for early and midseason oranges, Valencia oranges and grapefruit. The simple correlation coefficients between the expected price variables defined by $\sum_{j=0 \text{ to } t-1} \lambda(1-\lambda)^j op_{i,t-j}$ ranged from .91 to .99. Based on this situation, only the own-price variables were included in model (16). A grid search revealed that the best values for λ were .37 for early and midseason oranges and .26 for Valencia oranges. Ordinary least squares estimates of model (16) based on these values for λ are shown in Table 1. Corresponding seemingly unrelated regression estimates of model (16) are shown in Table 2. The results in these two tables are very similar. All the parameter estimates are significantly different than zero to the extent each estimated parameter is a number of times greater than its estimated standard error. At the end of the sample (t=35) the term $\delta_4(1-\lambda)^t$ is approaching zero and can be ignored for predicting future expected prices.

Table 1. Ordinary Least Squares Estimates of Model (16).

Parameter	Early and Midseason		Valencia	
	Est. Parameter	Est. Std. Error	Est. Parameter	Est. Std. Error
δ0	5.293	0.159	4.760	0.216
δ1or δ2	1.493	0.128	1.725	0.153
δ4	4.005	0.558	3.659	0.532
R-square	0.813		0.800	

Table 2. Seemingly Unrelated Regression Estimates of Model (16).

Parameter	Early and Midseason		Valencia	
	Est. Parameter	Est.Std. Error	Est. Parameter	Est.Std. Error
δ0	5.259	0.154	4.678	0.209
δ1or δ2	1.525	0.124	1.793	0.147
δ4	4.039	0.544	3.714	0.517
R-square	0.813		0.798	

Impact of Eliminating U.S. Orange Juice Tariffs on Orange Tree Planting Levels

The differential form of equation (13), without cross-price terms, can be written as

(17) $dn_{it} = \delta_1 \, dop^*_{i,t+1}$,

where dn_{it} and $dop^*_{i,t+1}$ are log difference measures of percentage changes in the tree planting level and the expected on-tree price for orange variety i, respectively. The parameter δ_1 is the elasticity of the tree planting level with respect to the expected on-tree price (the percentage change in the tree planting level given a one percent change in the expected on-tree price). Below, we use equation (17) to analyze how eliminating U.S. tariffs on OJ might impact orange tree planting levels.

Our preliminary analysis did not rule out the possibility that elimination of U.S. tariffs on orange juice could reduce the grower orange juice price by half the amount of the FCOJ tariff ($.15/PS) or somewhat more based on Spreen's analysis. We consider some long-run scenarios based on this possibility.

The prices in the planting equations are in terms of dollars per box and we first translate the possible $.15/PS price reduction into dollars per box. Pounds solids per box vary but over the five-year period from 1995-96 through 1999-00 have averaged 6.25 PS/box for early and midseason oranges and 7.04 PS/box for Valencia oranges. Hence, $.15/PS equals $.94/box for early and midseason oranges and $1.06/box for Valencia oranges.

At the end of the sample in 1999 (t=35), the logs of the expected on-tree prices (equation (13)) for early and midseason oranges and Valencia oranges are equal to 1.286 and 1.623, respectively. The corresponding prices (anti-logs) are $3.62 /box for early and midseason oranges and $5.07/box for Valencia oranges. Hence, with elimination of the tariffs, the early and mid season orange price would be expected to decrease by $.94/box to $2.68/box, while the Valencia orange price would be expected to decrease by $1.06/box to $4.01/box. The log changes in these prices are .30 for early and midseason oranges and .23 for Valencia oranges. From Table 2, the planting-price elasticities are 1.525 for early and midseason oranges and 1.793 for Valencia oranges. Using equation (17), application of these elasticities to the percentage changes in expected prices results in predicted decreases of 46% and 42% in early and midseason and Valencia orange tree planting levels, respectively. For each further $.01/PS reduction in the U.S. OJ price resulting from elimination of the U.S. tariffs, early and midseason and Valencia orange tree planting levels would decrease by about 3% to 4%. That is, a reduction in U.S. OJ prices of a few cents more than the a $.15/PS, resulting from the elimination of the U.S. OJ tariffs, may cut Florida orange planting levels roughly in half. We use these result below as a guide to developing scenarios for projecting Florida orange production.

Florida Orange Production Scenarios

Based on Florida's 2000 tree census and the incidence of the citrus tristeza virus (CTV) in Florida, the Florida Department of Citrus or FDOC has projected Florida orange production to decline somewhat in the next several years and then expand, assuming average yields and average planting levels (FDOC, 2001b)[11]. Changes in orange production are expected to result in similar changes in OJ production. The FDOC analysis, however, does not consider the possible impact on production due to lower U.S. prices and reduced planting levels that may result from the elimination of U.S. OJ tariffs. In this section, we consider some without-tariff scenarios for Florida orange production.

Our analysis suggests that U.S. OJ price levels and their impacts on future Florida orange production will depend on world demands by product form, origin and market, and world supplies by country and product form. However, due to lack information on many world supply/demand parameters[12], making detailed projections of supply changes by country, and demand and price changes by market is problematic; and, instead, we consider some simple scenarios for the U.S, based on the limited empirical results of this study.

In the short run, we initially assume that (a) elimination of the U.S. tariff reduces the U.S. price by roughly half the value of the tariff; and (b) the lower U.S. price results in reduced Florida orange planting levels. In the long run, we assume adjustments in demand and supply in world markets are such that the U.S. OJ price and planting levels continue to be at reduced levels, although not necessarily as low as in the short-run; we expect that the OJ price in the RW would increase and stimulate RW planting levels and production there. The assumption that price will be maintained at some reduced, without-tariff level requires a brief digression.

Based on equation (2b) and related results, changes in the U.S. price can be written as

$$dp_1 = \pi_{11}\,(dq_1 - d\alpha_1) + \pi_{12}\,(dq_2 - d\alpha_2), \tag{18}$$

where $d\alpha_s = \sum_r \sum_i d\alpha^r_{si}$. The terms $d\alpha_1$ and $d\alpha_2$ reflect demand growth for Florida and Brazil OJ, respectively. Consider the maintenance of the U.S. price at a without-tariff, reduced level. This possibility requires that, in equation (18), $dp_1 = 0$ (for all periods after the initial decline in the OJ price as a result of eliminating the U.S. tariffs) which, in turn, implies

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[11] The FDOC estimates did not consider the possibility that trees planted on CTV resistant rootstocks trees may have lower yields compared to trees on sour-orange rootstock being lost to CTV, suggesting the FDOC estimates may overstate the production potential.

[12] In additional, incidences of citrus diseases make estimation of Brazil orange production difficult; future supply shocks due to weather are not known; and future expansions/contractions in world income and demand levels are not clear.

(19) $d\alpha_1 + (\pi_{12}/\pi_{11})\, d\alpha_2 = dq_1 + (\pi_{12}/\pi_{11})\, dq_2$.

Equation (19) indicates that the U.S. price will remain unchanged when aggregate growth in demands for Florida OJ and RW OJ weighted by the factor (π_{12}/π_{11}) is equal to growth in supply of Florida OJ and RW OJ also weighted by the factor (π_{12}/π_{11})—based on equation (10), $(\pi_{12}/\pi_{11}) = .72$. The U.S. price will increase when the growth in (weighted) aggregate demand exceeds the growth in (weighted) aggregate supply, and vice versa. For declining Florida production scenarios ($dq_1 < 0$), we assume that there is growth in demand for Florida OJ ($d\alpha_1 > 0$), in which case, the U.S. price remains unchanged only when RW supplies grow sufficiently faster than the growth in demand for RW product. If this is not the case (due, perhaps to production constraints related to initial low nonbearing tree populations, growing conditions and diseases in the RW, and/or relatively strong demand growth in RW markets) the U.S. price would tend to increase, supporting more moderate planting levels and production declines.

Based on the foregoing assumptions and digression, we consider four Florida planting/production scenarios over the projection period: (a) the average Florida orange planting level for the past three years, (b) no additional trees are planted in upcoming years, (c) half the average planting level,(d) three-fourths the average planting level. Scenarios (a) and (b) are provided as bases for comparison, with Scenario (a) being the FDOC estimate of production under the assumption that the tariffs continue at current levels. Scenario (c) is an extension of the short-run expectation to the long run using the results based on equation (17) as a guide to set the planting level at half the average. Scenario (d) is provided to account for the uncertainty of the without-tariff impacts on prices and planting levels, and to allow for the possibility that favorable demand growth for Florida, as well as RW OJ products, may alleviate the negative impacts of the tariff on U.S. prices and Florida planting levels.

A projection period from 2001-02 through 2021-22 is considered. The model developed by the FDOC to estimate Florida orange production (FDOC, 2001b) is used to estimate production for our four scenarios. The model works by projecting orange acreage by age based on assumed planting and loss rates. Production estimates are then obtained by applying average yields (boxes per acre by age) to the projected acreage. This model assumes CTV will eliminate about 12 million orange trees in the next eight years. Loss rates due to factors other than CTV vary by age of the acreage but averaged about 2.5%. Average yields for the 1993-94 through 198-99, excluding the 1999-00 El Nino impacted season, were used.

Estimated Florida orange production for the four planting scenarios are shown in Table 3. Assuming average planting levels, orange production is estimated to expand to 260 million 90 pound boxes in 2021-22. Alternatively, assuming zero planting levels, production is estimated to contract to 139 million boxes in 2021-22. Our estimate of the no-tariff production level in 2021-22 falls in this range. If the planting level is half the average, production would decrease to198 million boxes in 2021-22, or 23.8% below the projection based on average planting levels. Alternatively, if the planting level is three-fourths the average, due say to favorable demand growth for Florida product, production would decrease to229 million boxes in 2021-22, or 11.9% below the projection based on average planting levels. Other scenarios might be considered, but these results provide an indication of the range of effects that could occur.

Finally, it should be noted that elimination of the U.S. tariff may result in a price that is below the cost of production for some Florida growers. Muraro and Still have estimated the average grower cost of delivering an orange PS to a processor at $.73/PS. As a result of without-tariff, low prices, some grower may experience losses and go out of business. Likewise, for some growers, low prices may result in reduced grove care and lower yields. To the extent these possibilities occur, Florida orange production could decline by more than indicted by Scenarios (b) and (c) in Table 3.

Table 3. Florida Orange Production Projections (a).

Season	Planting Assumption			
	Average	Zero	½ Avg.	3/4 Avg.
	Million Boxes			
2001-02	237	237	237	237
2002-03	231	231	231	231
2003-04	227	225	226	226
2004-05	227	222	224	226
2005-06	230	220	225	227
2006-07	234	219	226	230
2007-08	238	216	227	233
2008-09	243	213	228	235
2009-10	246	210	228	237
2010-11	250	206	228	239
2011-12	251	200	226	239
2012-13	253	194	224	239
2013-14	254	188	221	237
2014-15	255	181	218	236
2015-16	255	174	214	235
2016-17	255	167	211	233
2017-18	256	160	208	232
2018-19	257	154	205	231
2019-20	258	148	203	230
2020-21	259	142	201	230
2021-22	260	136	198	229

(a) Assumes average yields (boxes/acre) over 1993-94 through 1999-00, excluding 1998-99 assumed; and tristeza phased in over next eight years.

Concluding Comments

In this paper, a demand system model was developed to analyze how elimination of U.S. tariffs on OJ may impact grower prices. Products were differentiated by form (FCOJ and NFC) and origin (U.S. and RW). The analysis focused on the importance of substitution between these different products in determining price impacts resulting from elimination of U.S. OJ tariffs. The results suggest that the price reductions due to elimination of the tariffs may be smaller than those predicted by the alternative models. However, uncertainty exists with respect to the amount of substitution between products, and the substitute demand system model yielded similar results as the alternative models when the substitution was assumed to be relatively strong.

The belief that elimination of tariff may reduce the U.S. price by the amount of the tariff is not supported by the present analysis. The largest impact estimated was a price reduction of about 63% of the tariff amount, and, if substitution between products is weak, the impact might be much less.

Although there is uncertainty about the magnitudes of the impacts on the OJ prices due to elimination of the U.S. tariffs, the results have a straightforward policy implication for supporting Florida and U.S. orange growers. The results based on the substitute demand system model show how the price impact becomes smaller as substitution between the U.S. and the RW OJ products decreases. Promotional programs that differentiate between OJ produced in the U.S. versus OJ produced in the RW may reduce the substitution that occurs between these products, and, hence, reduce the impact on U.S. prices that elimination of U.S. tariffs might have.

In the long run, lower prices resulting from elimination of the U.S. tariffs can be expected to lead to lower Florida orange production levels. If elimination of the tariffs were to reduce OJ prices by about half the value of the FCOJ tariff, we estimate that orange planting levels would be cut by nearly 50% and orange production would decline by 24% by 2021-22. Sustained low prices may result in further production declines to the extent these prices are below the cost of production for some growers and force them out of business, and/or the low prices result in reduced grove care and lower yields. On the other hand, growth in demand for Florida OJ products in world markets may alleviate the negative effects on U.S. OJ prices and Florida production, as suggested by our scenario where Florida orange production is reduced by about 12% without the tariffs in the long run. The ultimate impacts of demand growth for Florida products on prices and production further depends on RW supply and demand growth for OJ.

It should also be noted that the assumption of competitive behavior underlying the preceding models may not always be appropriate. At times, non-competitive behavior has occurred in the world OJ industry. The Brazilian OJ industry is dominated by a few processors and the possibility of oligopolistic behavior can not be discounted. For example, elimination of the U.S. tariff may have little or no effect on the U.S. price to the extent Brazilian processors decide it would be more profitable to pocket the tariff and maintain pre-tariff market allocation levels. The demand for OJ tends to be inelastic at the processor level so that a price decline would result in reduced revenue.

Finally, the results of this study are a reminder of the importance of demand growth and product differentiation in supporting grower prices. Brown, Lee and Spreen found that the "free rider" problem, where some foreign OJ imports benefitted from OJ advertising by the FDOC without contributing to the FDOC's costs, resulted in an erosion of the advertising impact. Advertising that both grew demand and differentiated Florida OJ was one strategy suggested to alleviate this problem. The present results further suggest that this strategy might be considered to alleviate the negative price impacts in the event that the U.S. tariffs on OJ are eliminated or reduced.

Appendix A: Perfect Substitute Model

Analysis of the impact of the tariff under the assumption that all OJ products are perfect substitutes provides a simplified picture of the basic supply and demand forces at work. Consider the international trading of FCOJ, with a focus on the U.S. and the rest of the world (RW) as both suppliers and markets for this product. Consider the case where the U.S. market absorbs all OJ produced in the U.S. plus part of the FCOJ production in the RW. (A corner solution in context of the spatial equilibrium model.) This case roughly depicts the situation in the U.S. in the latter half of the 1980s and early 1990s when Florida OJ production was sharply reduced by a series freezes, and the volume of NFC produced was much smaller than today.

Let total supplies of OJ from the U.S. and the RW be denoted by q_1 and q_2, respectively. Assume these supplies are fixed and consider the short-run adjustment process of allocating the supplies to the U.S. and the RW. Specifying the demands for OJ in the U.S. and the RW be as functions of prices, we denote the quantity demanded in the U.S. by $f_1(p+c)$ and the quantity demanded in the RW by $f_2(p)$, where p is the price of OJ in the RW, c is the cost of transferring OJ from the RW to the U.S., p + c is the U.S. price, and $\partial f_1/\partial p < 0$ and $\partial f_2/\partial p < 0$. (A measure of p might be the Brazilian FOB Santos price.) The transfer cost c includes the U.S. tariff. OJ produced in the RW is assumed to be a perfect substitute for OJ produced in the U.S., and the RW is assumed to supply OJ to both the U.S. and the RW, receiving the same net price p in each market. Prices are determined by excess supply and demand. The quantity of U.S. excess demand is $f_1(p + c) - q_1$ which varies inversely with p , while the quantity of excess supply in the RW is $q_2 - f_2(p)$ which varies directly with p. Setting excess supply equal to excess demand and rearranging terms we have

(A1) $$q_1 + q_2 = f_1(p + c) + f_2(p),$$

which is an equilibrium equation that can be used to determine the impact of the tariff on price; a change in c (due to a change in the tariff) results in a change in the equilibrium price level of p (the level of p that equates excess supply and demand).

Elimination of the U.S. tariff makes it more profitable for the RW to reallocate OJ from the RW to the U.S. As OJ is taken out of the RW, p increases until prices in the U.S. market and the RW are the same. To determine the impact of changing the tariff, totally differentiate the latter equilibrium equation, holding supply constant, and find

(A2) $$0 = \partial f_1/\partial p\,(dp + dc) + \partial f_2/\partial p\,(dp).$$

Solving the above result for dp, we find

(A3) $$dp = - dc\,[\partial f_1/\partial p/(\partial f_1/\partial p + \partial f_2/\partial p)].$$

Hence, the change in the U.S. price is

(A4) $$dp + dc = (1 - [\partial f_1/\partial p/(\partial f_1/\partial p + \partial f_2/\partial p)])dc.$$

The result for dp is positive, given the negatively sloped demands and dc is negative for reducing or eliminating the tariff. The change in the U.S. price is negative for the same assumptions.

If the demand slopes for the U.S. and the RW markets are the same ($\partial f_1/\partial p = \partial f_2/\partial p$), the price impact is dp = -1/2 dc. Assuming only FCOJ is traded, elimination of the tariff (dc = -.289/PS) would increase price p by \$.145 and decrease the U.S. price by dp+dc = -1/2 dc + dc = - \$.145. That is, the U.S. price would decrease by half the tariff rate. If the magnitudes of the demand slopes in the U.S. and the RW are not equal, the results could be very different. Letting the demand slope in the RW be k times the demand slope in the U.S. ($\partial f_2/\partial p = k(\partial f_1/\partial p)$, we find dp = - dc/(1+k) and dp +dc = dc(k/(1+k). Hence as k increases or the demand slope in the RW increases in absolute value (becomes more elastic) relative to the demand slope in the U.S., the positive impact on p becomes smaller and the negative impact on the U.S. price becomes greater. On the other hand, as k decreases or the demand slope in the U.S. ($\partial f_1/\partial p$) increases in absolute value relative to that in the RW, the positive impact on p becomes larger and the negative impact on the U.S. price smaller. In a study of OJ advertising, Brown et al. estimated the term $\partial f_1/\partial p/(\partial f_1/\partial p + \partial f_2/\partial p)$ at 1/3, and using this result in equations (A3) and (A4) under the assumption that only FCOJ is traded, elimination of the tariff would increase the RW price by about \$.10/PS and decrease the U.S. price by about \$.19/PS.

Appendix B: Spatial Equilibrium Model

A general approach to estimate how tariffs impact prices is through the spatial equilibrium or mathematical programing model developed by Takayama and Judge.

Consider two origins of production, the U.S. and the RW, and two product forms, FCOJ and NFC. Let q^r_{si} be the quantity of product form i from supply region s in market r (r = 1 for the U.S., r = 2 for the RW; s = 1 for the U.S., s = 2 for the RW; i = 1 for FCOJ and RECON, i = 2 for NFC); $q^r_{s.} = \sum_i q^r_{si}$ or the quantity of all product forms from supply region s in market r; and let q_s be the quantity of OJ, of all product forms produced in supply region s. In the perfect substitute model, OJ is not differentiated and we define the quantity of OJ of all forms from all supply regions in market r by $q^r_{..} = \sum_s\sum_i q^r_{si}$.

In the spatial equilibrium framework, the amounts of OJ from different suppliers are allocated to different markets so as to maximize the area under the demand functions net of transfer costs. In our specification, transfer costs include processing, storage, transportation and tariff costs. Competitive behavior is assumed. Formally, the perfect substitute model can be written as

(B1) $\text{maximize} \sum_r \int p^r(q^r_{..})dq^r_{..} \; - \; \sum_r\sum_s c^r_s\, q^r_{s.}\,,$

subject to (a) $q^r_{..} \leq \sum_s q^r_{s.}\,,$
(b) $q_s \geq \sum_r q^r_{s.}\,;$

where p^r is the retail price of OJ in market r and is inversely related to $q^r_{..}$ (this is the inverse demand function corresponding to the direct-demand function in Appendix A where quantity demanded is specified as a function of price); and c^r_s is the cost of transferring OJ from supply region s to market r (c^r_s includes the tariff imposed in market r on OJ from supply region s). Constraint (a) requires that the quantity sold does not exceed quantities transferred while (b) requires that quantities transferred from the U.S. and the RW do not exceed available supplies. Possible solutions to model (B1) include those (corner solutions) where the U.S. imports but does not export OJ, or exports but does not import; another possible solution is where the U.S. consumes all of its domestic supply and neither imports or exports OJ.

The assumption in model (B1) that FCOJ and NFC are perfect substitutes may be an oversimplification for some markets (e.g, in the U.S. market, as discussed by Brown and Lee). A model that allows for differentiation by product form (FCOJ versus NFC) has been analyzed by Spreen. Similar to model (B1), the differentiated-product-form model allocates the amounts of FCOJ and NFC from different suppliers to different markets so as to maximize the area under the demand functions net of transfer costs. Again, competitive behavior is assumed, with the differentiated products treated as close substitutes. Formally, this model can be written as

$$\text{(B2)} \quad \text{maximize } \sum_r \int \sum_i p^r_i(q^r_{.1}, q^r_{.2})\, dq^r_{.i} \; - \; \sum_r \sum_s \sum_i c^r_{si}\, q^r_{si} ,$$

$$\text{subject to} \quad \text{(a)} \quad q^r_{.i} \le \sum_s q^r_{si} \text{ , and}$$
$$\text{(b)} \quad q_s \ge \sum_r \sum_i q^r_{si} ,$$

where $\int \sum_i p^r_i(q^r_{.1}, q^r_{.2})\, dq^r_{.i}$ is a line integral; $q^r_{.i}$ is the quantity of OJ of product form i, from all supply regions, sold in market r; p^r_i is the retail price of product form i in market r and is dependent on quantities $q^r_{.i}$ (i=1,2) through the inverse demand function $p^r_i(q^r_{.1}, q^r_{.2})$; and c^r_{si} is the cost of transferring product i from supply region s to market r (c^r_{si} includes the product-form, specific tariff imposed in market r on product i from supply region s). Note that in (B2) OJ product is only differentiated by product form—OJ products of the same form but from different supply regions are perfect substitutes.

The derivatives of the line integral in problem (B2) with respect to quantities must result in the inverse demand functions, i.e., $\partial \int \sum_i p^r_i(q^r_{.1}, q^r_{.2})\, dq^r_{.i} / \partial q^r_{.i} = p^r_i(q^r_{.1}, q^r_{.2})$[13]. In addition, the matrix of partial derivatives of the inverse demand functions with respect to quantities, $[\partial p^r_k/\partial q^r_{.i} = \partial p^r_i/\partial q^r_{.k}]$, must be symmetric (integrability condition)[14]. The latter condition will hold for (Hicksian) real-income-held- constant or compensated demand functions but, in general, will not hold for (Marshallian) uncompensated demand functions (see, e.g., Silberberg). Compensated

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[13] The line integral is similar to a distance function for market r times consumer expenditures (m) on the products in question; e.g., letting $d^r(q^r_{.1}, q^r_{.2}, u)$ be a distance function where u is utility, we have $(\partial d^r(q^r_{.1}, q^r_{.2}, u)/ \partial q^r_{.i})\, m = p^r_i(q^r_{.1}, q^r_{.2})$ (Deaton and Muellbauer).

[14] For cases where integrability conditions are not satisfied, Takayama and Judge propose an alternative programing model.

(uncompensated) demand functions are appropriate when quantity changes impact prices through substitution effects only (both substitution and scale effects) (see, e.g., Anderson). It should also be noted that a complete system of compensated inverse demand functions in (B2) does not satisfy the second-order condition of strict negative definiteness---the compensated demand functions are homogenous of degree zero in quantities, and the Antonelli matrix of derivatives of the compensated inverse demand functions with respect to quantities is negative semidefinite (singular in the quantity vector).

Like model (B1), the optimal allocation for (B2) involves corner solutions where a producer may supply some markets but not others. In Spreen's application of the spatial equilibrium model (B2), constraints were included that require minimal amounts of imports for blending purposes. The results of this study indicate that elimination of the U.S. tariff reduces the U.S. OJ price by about \$.18/PS. This study also included a long-run analysis where prices obtained from supply and demand in one period impact tree planting levels in the next period which, in turn, impact future production (a newly planted tree takes about three years to bear fruit for commercial use).

In contrast to the differentiated-product-form model, OJ could be differentiated by supply region instead of product form. The problem for this possibility can be written as

(B3) maximize $\sum_r \int \sum_s p^r_s(q^r_{1.}, q^r_{2.}) dq^r_{s.} \; - \; \sum_r \sum_s c^r_s q^r_{s.}$,

subject to (a) $q^r_{s.} \leq \sum_i q^r_{si}$,
(b) $q_s \geq \sum_r q^r_{s.}$,

where p^r_s is the retail price of product from supply region s in market r, and $p^r_s(q^r_{1.}, q^r_{2.})$ is an inverse demand function where price p^r_s is a function of quantities $q^r_{s.}$ (s=1,2). In (B3), OJ product is only differentiated by origin—OJ products from the same supply region but of different forms are perfect substitutes. Differentiation by origin seems to exist in trading OJ, based on price premiums commanded by some country-specific product. A natural extension to models (B2) and (B3) is to differentiate OJ by both product form and origin, as in the substitute demand system model, equations (3a) through (9), and Appendix C.

Appendix C: Substitute Demand Model

Equations (3a) through (3c) can be motivated using the spatial equilibrium model (Takayama and Judge). Consider the problem of maximizing the area under the different OJ demand curves net of production and transfer costs, i.e.,

(C1) maximize $\sum_r \int \sum_i \sum_s p^r_{si}(q^r_{11}, q^r_{12}, q^r_{21}, q^r_{22}) \, dq^r_{si} \; - \; \sum_r \sum_s \sum_i c^r_{si} q^r_{si}$,

subject to $q_s \geq \sum_r \sum_i q^r_{si}$.

For each market the area under the differentiated demands is expressed by a line integral.

The Lagrangian function for this problem is

(C2) $L = \sum_r \int \sum_i \sum_s p^r_{si}(q^r_{11}, q^r_{12}, q^r_{21}, q^r_{22})\, dq^r_{si} \;-\; \sum_r \sum_s \sum_i c^r_{si}\, q^r_{si} \;+\; \sum_s p_s(q_s - \sum_r \sum_i q^r_{si}),$

where p_s is a Lagrange multiplier.

Assuming interior solutions, the first order conditions for (C2) are

(C3) $\partial L/\partial q^r_{si} = p^r_{si}(q^r_{11}, q^r_{12}, q^r_{21}, q^r_{22}) - c^r_{si} - p_s = 0$
(C4) $\partial L/\partial p_s = (q_s - \sum_r \sum_i q^r_{si}) = 0.$

The Lagrange Multipliers are OJ shadow prices for the different origins. Assuming $p^r_{si}(q^r_{11}, q^r_{12}, q^r_{21}, q^r_{22})$ is linear, (C3) can be solved to find (3b).

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