# Modeling Florida Fresh Tomato Supply Response:

## Composite Switching Regressions with Variable Weather-Determined Lags

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# Modeling Florida Fresh Tomato Supply Response:

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**Abstract**: A supply-response model for Florida fresh tomatoes is specified to analyze the impacts of the U.S. Department of Commerce's suspension agreement which governs imports of fresh tomatoes from Mexico. The particular focus is on the impact of the "reference" price which causes Mexican imports in a given week to cease if import prices in the prior week fall to the reference price. Using weekly weather data, a growing degree day (GDD) variable is constructed which predicts week of first harvest and duration of harvest. The GDD variable is used to construct the appropriate, variable lag length for weekly acres planted in four Florida production regions. A composite switching-regime model is estimated in which the regime prior to the suspension agreement occurs at a known time. The other two regimes occur when Nogales f.o.b. price are "near" or not near the reference price. Preliminary results suggest weekly Florida shipments of fresh tomatoes are more own-price elastic when Nogales f.o.b. prices near the reference price.

**Keywords**: supply response, switching regimes, growing degree days

**JEL Codes**: F14, Q11, Q17

# Modeling Florida Fresh Tomato Supply Response: Composite Switching Regressions with Variable Weather-Determined Lags

Trade disputes between Florida and Mexico grower-shippers of fresh tomatoes have a long and checkered past. The U.S. trade embargo with Cuba in 1961 resulted in two supply regions for field-grown, fresh tomatoes during the winter months in the United States: Florida and Sinaloa, Mexico. At various times during the past 40 years, Florida grower-shippers have accused Mexican grower-shippers of dumping fresh tomatoes in the United States. The most recent dumping dispute was resolved in November 1996 when the so-called suspension agreement was implemented. The main feature of the suspension agreement is a trigger price—known as a “reference” price—which curtails Mexican imports. If f.o.b. prices of Mexican fresh tomatoes fall to the reference price in a particular week, the following week imports are prohibited. The initial reference price agreement was put in place November 1, 1996 and was amended in August of 1998 to provide a second reference price for regions of California and Baja, Mexico versus Sinaloa, Mexico. The suspension agreement was renewed on November 1, 2003 with the reference price increasing by 2.9%.

Limited research has assessed the impacts of the reference price on supply response for fresh tomatoes which are a highly perishable product. This research focuses on Florida grower-shippers’ supply-response given the institutional incentives established under the suspension agreement. We seek to verify whether there are distinguishable differences in supply response before and during the suspension agreement. During the suspension agreement, we also seek to verify whether supply responses change when declining market prices approach the reference price. Some observers contend that Florida grower-shippers could act in concert to increase shipments when they observe Mexican f.o.b. prices falling near the reference price in an effort to garner market share when the binding reference price halts Mexican imports the following week.

The empirical model used to investigate the potential regime switches owing to policy changes is a supply-response model which accounts for the unique agronomic features of tomato plants. In particular, we construct measures of growing degree days from daily weather observations to obtain estimates of the timing and magnitude of potential tomato harvests. Coupled with weekly acreages planted in Florida, the growing degree days afford a season-specific measure of how long lags are between plantings and harvest. Instead of imposing a fixed lag length, season-specific growing conditions are used to construct a variable lag length for acres planted.

After specifying the supply-response model, we proceed to use deterministic switching-regime models to assess whether (i) the suspension agreement has changed Florida supply responses measurably and (ii) whether Florida supply response differs when Mexican f.o.b. prices approach the reference price. First, we turn to the specification of the supply-response model.

## Supply-Response Models

The majority of supply response models for agricultural commodities and products have relied on fixed lag structures of some kind to explain or predict supply response. The motivation for such fixed lags may be economic, biological, or simply a matter of tractability. By contrast, the present model employs agronomic and weather information to express current shipments (production) as a function of lags that can vary in length within and across growing seasons. In particular, the relationship between potential tomato yields and growing degree days is used to identify both the timing and duration of potential harvest. Variability in daily temperature is accounted for in growing degree day calculations so that location-specific weather conditions from time of planting lead to a particular time of first harvest and potential duration of that harvest. As weather conditions change, the timing and duration of harvest will change accordingly. The current model exploits this information to explain current period shipments of fresh tomatoes grown in the four major producing regions of Florida.

Accounting for agronomic and weather-induced changes in supply response is important in the context of recent trade disputes concerning imports of fresh tomatoes from Mexico, which compete directly with Florida-grown fresh tomatoes. In November 1996, the U.S. Department of Commerce implemented a reference price on imports of fresh tomatoes from Mexico during winter and spring months. The reference price serves as a floor price: once f.o.b. prices at the U.S. border dip to the reference price, imports in the following week are prohibited. In anticipation of a binding floor price, some Florida grower-shippers might choose to harvest more tomatoes in an effort to drive the market price towards the reference price. By carefully accounting for weather conditions and potentials harvests, we may be able to identify how Florida grower-shippers respond in such market conditions.

### *Sequential Production of Fresh Tomatoes*

The bulk of Florida's fresh tomatoes in the "winter" are produced in four distinct areas: Dade, East Coast, Southwest, and Palmetto-Ruskin. Owing to subtle differences in climate across the four regions, tomatoes are shipped sequentially from mid-October to the end of June. To facilitate continuous shipping, tomatoes are planted from transplants beginning in the first week of August through mid-March (see Figure 1). Dade County provides a bridge between early and late season plantings in the Southwest and Palmetto-Ruskin regions. The East Coast adds small acreages planted throughout the season. Many large grower-shippers coordinate planting, growing, and harvesting across these four regions over the entire season.

Tomato varieties grown on poles are indeterminate, which allows for nearly continuous harvesting over a prolonged period. The period over which tomatoes are harvested commercially depends in large measure on the current profitability of harvesting them: if prices are very low, many tomatoes may go unharvested so that only the largest, best quality fruit may be harvested. If prices are low, but still profitable to pay for harvesting and processing costs, nearly all marketable fruit, including lower quality tomatoes, may be harvested.[1] This physiological trait of tomato plants allows grower-shippers to adjust harvesting intensity to market conditions. This trait of indeterminate tomatoes has not gone unnoted: Shonkwiler and Emerson (p. 635), for example, observed that fresh tomato yield is a function of the number of times the crop is harvested, which, in turn, depends on current product prices and harvesting costs.

The timing of harvest as well as the potential quantity of fruit available for harvest can be predicted using degree days (Marcelis et al.). Based on field trials in selected Florida production areas, Scholberg et al. have estimated the relationship between fruit dry matter—mature tomatoes are about 5% dry matter by weight—and degree days. The simplest formula for calculating growing degree days (GDD) is

$$GDD = \sum \left( T_{\max} - T_{min} \right) / 2 - T_{base} \tag{1}$$

where $T_{max}$ and $T_{min}$ denote daily maximum and minimum temperatures while $T_{base}$ represents the minimum temperature at which tomatoes may undergo chilling injury (LeStrange et al.). The summation sign indicates daily values are accumulated as the growing season progresses. The formula used here for calculating GDD values multiplies each day's GDD value times day length so that warmer temperatures in the winter contribute less to summed GDD values than would the same temperatures in the summer. The timing of first and subsequent harvests can then be

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[1] In contrast to some types of citrus which can be "stored" on the tree, tomatoes may not be stored on the vine because maturation continues under favorable climatic conditions.

predicted using the cumulative GDD values at any given date from planting. Agronomists refer to such measures as "thermal time" to reflect the fact that plant growth hinges critically on temperatures over the course of a plant's development.

Scholberg and Scholberg et al. estimate fruit dry matter as a linear function of GDD. Due to variability in daily temperatures, quantity of fruit dry matter varies nonlinearly with calendar time even though it is a linear function of thermal time. For example, acres planted in Dade County in the second week of September would cease to be harvested after 12 weeks whereas acres planted in Dade in the second week of October could still produce fruit over 14 weeks later owing to lower temperatures.

Acres planted in each of the four regions are matched with daily weather observations from neighboring weather stations to generate degree days.[2] Each week planting occurs in a production region, a matched cumulative GDD measure is generated in order to predict when harvest on those acres planted would occur and how much fruit dry matter would be available over the course of that harvest period. In an analogous fashion, the variables representing acreage are only "switched on" when the cumulative degree days indicate that harvest would be available from those particular planted areas. We choose this method for gauging the effects of acreage rather than lagging acreage relative to current shipments by some arbitrary time period which remains constant within any growing season as well as across all growing seasons.

Total acres planted weekly, regardless of type of tomato, are available for each of the four production regions. However, only aggregate shipments of cherry, roma, and round tomatoes from all regions are reported. Another complication is that weekly prices are available

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[2] Davidson et al. document differences in temperature between adjacent weather stations and various positions in the field relative to the plant's canopy. They indicate adjacent weather stations give readings different from those recorded in the field. However, the readings are sometimes lower and other times higher depending on a variety of factors. Hence, there is no clear direction of bias from using temperature observations from adjacent weather stations.

only for mature green and vine ripe round tomatoes. Given these limitations, we model current shipments of round tomatoes as follows

(2) $$q_t = q(p_t, \mathbf{x}_t, A_{i,t-h(GDD_t)},) \quad i = 1,\ldots,4;\ t = 1,\ldots,T$$

where $q_t$ denotes quantity of round tomatoes shipped in a given week in a particular season, $p_t$ represents the weighted average price of mature green and vine ripe tomatoes in week $t$, $\mathbf{x}_t$ denotes a vector of exogenous shipment shifters such as wages and other input prices, and $A_{i_{t-h(GDD_t)}}$ is the corresponding total acreage from all $i$ regions (Dade, East Coast, Southwest, and Palmetto-Ruskin) "harvestable" in week $t$ as determined by matching cumulative degree days ($GDD_t$) with acreage planted in prior weeks of $t$-$h$ (i.e., $A_{i_{t-h(GDD_t)}}$). Notice that the lag length $h$ depends on degree days as mentioned above. The empirical version of this shipment equation is estimated assuming a linear functional form and an additive disturbance.

## Data and Descriptive Statistics

Weekly acreage planted for the four main fresh tomato production regions in Florida—Dade, East Coast, Southwest, and Palmetto-Ruskin—are only available for the eight growing seasons beginning in 1993-94 and ending 2000-2001. Due to the limitations in the acreage planted data, we must limit our analysis to these eight seasons. The U.S. Department of Commerce implemented the reference price beginning November 1, 1996. Hence, there are three seasons in the sample before implementation of the reference price—1993-94 through 1995-96—and five seasons with the reference price in effect—1996-97 through 2000-01. This split yields 101 and 174 weekly observations before and during the suspension agreement. On August 21, 1998 the first reference price of \$0.2068/lb. was raised by 2.33% to \$0.2108/lb. This change in the reference price makes it possible to examine potential changes in the market at the lower reference price (68 observations from two seasons) versus the higher price (106 observations over the last three seasons).

Aggregate Florida shipments of cherry and round tomatoes are available during the same period. Shipments of roma tomatoes are only available in the last two seasons. Florida f.o.b. prices of vine ripe and mature green tomatoes are recorded but prices of other types of tomatoes are not reported. Given these limitations, we use quantities of round tomatoes and a weighted average price of mature green and vine ripe f.o.b. prices. As previously mentioned, daily weather observations on minimum and maximum temperatures (Climate Analysis Branch) are employed to construct weekly growing degree days and acres available for harvest. See the appendix for details about the choice of appropriate weather stations.

Weekly observations on relevant input prices are simply not available. The unit costs of picking and packing relative to current price usually determine whether tomatoes will be harvested or not. Labor costs represent a large portion of the picking and packing costs. As a proxy for these labor costs, we use the average hourly earnings of food and kindred workers in Florida. When a particular week falls entirely within a month, that month's value for average hourly earnings is used; when a week straddles two months, a weighted average of the two monthly values is constructed using the number of days in the respective months as weights.

Several changes in prices, shipments, and acreages are prominent over the seven seasons analyzed here (see Table 1). Florida weekly shipments have increased measurably on a relatively smaller base of acreage planted. While average shipments from Florida have increased, there was a notable increase during the first reference price period. During the second reference price period, weekly shipments continued to grow while mean f.o.b. price declined to about the pre-suspension agreement average. Part of the continued growth in shipments since

1998 occurred as acreages planted increased modestly in the Dade and Southwest regions. While average Florida f.o.b. prices have not declined during the suspension agreement, minimum weekly prices have tended to increase, perhaps as a result of the reference price (see Figure 2). With the exception of the 2000-01 season, minimum weekly prices in the middle of the season (late December to late February) as well as in the late season (mid-April to the end of May) have exceeded pre-suspension low prices by about $0.50/carton.

Although weekly average shipments of Mexican vine ripe tomatoes increased slightly (11%) in the first reference price period, quantities crossing at Nogales, AZ declined appreciably (38%) during the second reference price period. Perhaps not surprisingly, the incidence of a binding reference price increased markedly in the second reference price period as well. The USDA's Agricultural Marketing Service reports low and high prices for two sizes of vine ripe tomatoes, 5 x 5 and 5 x 6. The latter are slightly smaller and generally fetch lower prices. The low prices for both sizes increased with the implementation of the reference price but increased by less in the second reference price period, largely due to a more frequently binding reference price in that period.

**Estimation and Inference**

The empirical version of the supply-response equation for Florida fresh tomatoes is specified in quantity-dependent form

$$(3) \qquad q_t = \beta_0 + \beta_1 p_t + \beta_2 w_t + \sum_{i=1}^{4} \beta_{i+2} A_{i,t-h(GDD_t)} + \varepsilon_t \qquad t = 1, \ldots, T$$

where $q_t$ denotes weekly quantity of round tomatoes shipped from Florida, $p_t$ is the weighted average weekly price of vine ripe and mature green tomatoes, $w_t$ is the wage rate, $A_{i,t-h}$

represents available weekly acreages to be harvested in each of the four production regions, and $\varepsilon_t$ denotes the stochastic error.

There may be reason to believe price and quantity in the fresh tomato market are determined simultaneously. Accordingly, we tested for weak exogeneity of the weighted-average price in the shipment equation using the Durbin-Wu-Hausman test statistic. The null hypothesis, $E(p_t \varepsilon_t) = 0$, is rejected ($\chi^2_{(1)}$=9.334, p-value=0.002).[3] Rejection of the null is accompanied by the intuitively appealing result that the own-price coefficient for the instrumental variable estimation is positive ( $\hat{\beta}_{IV} = 734.2$ ) whereas in the OLS version it is negative ( $\beta_{OLS} =$ -1,401.2 ).

*Deterministic Switching Based on Policy Change*

The so-called suspension agreement, in which reference prices were established for imports of fresh tomatoes from Mexico, was implemented November 1, 1996. The new policy regime suggests there might be measurably different Florida shipment behavior before the agreement vis-à-vis during the new agreement. Because the time period in which the suspension agreement is known, a switching-regime model in which the deterministic switching rule is based on the time when the policy change occurred might be appropriate (Goldfeld and Quandt, 1973a). To adapt the deterministic switching model to the present supply-response equation requires accounting for the correlation between own-price and errors both before and during the suspension agreement. We employ a two-step procedure for testing for distinct switching

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[3] The instruments for the IV version include all predetermined variables in the equation as well as the retail prices of iceberg lettuce and fresh tomatoes (Bureau of Labor Statistics) and total disposable personal income (Bureau of Economic Analysis). Monthly observations were converted to weekly observations as was done with the average hourly earnings variable. The correct degrees of freedom for the Durbin-Wu-Hausman test equal the number of potentially endogenous variables in the model (Davidson and MacKinnon, 2003, p 341).

regimes. The standard approach is implemented by maximizing the following log likelihood function

$$(4)\qquad \ln L = -\frac{T}{2}\ln 2\pi - 0.5\sum_{t\in T_1}\ln\sigma_1^2 - 0.5\sum_{t\in T_2}\ln\sigma_2^2 - 0.5\sum_{t\in T_1}\frac{(y_t - \mathbf{X}_t\boldsymbol{\beta}_1)^2}{\sigma_1^2} - 0.5\sum_{t\in T_2}\frac{(y_t - \mathbf{X}_t\boldsymbol{\beta}_2)^2}{\sigma_2^2}$$

where the dependent variable, $y_t$, corresponds to $q_t$, in (3), $\mathbf{X}_t$ is a row vector of observations on all right-hand side variables in (3), and $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ are conformable vectors of parameters to be estimated. $T_1$ and $T_2$ denote two consecutive, mutually exclusive subsamples for which $T_1 + T_2 = T$. We replace weighted-average prices which appear in $\mathbf{X}_t$ with their predicted values using instruments, $\mathbf{W}_t$, resulting in a limited information estimator. As a two-step estimator, the limited information estimator will not yield consistent estimates of the asymptotic covariance matrix of the parameters but for purposes of the following likelihood ratio tests, the estimation procedure is appropriate.

Note that a limited information estimator using $\mathbf{W}_t$ assumes that relevant instruments should use the entire sample for generating the predicted values. But if two regimes do exist—before the suspension ($T_1$=101) and during the suspension agreement ($T_2$=174)—it may be reasonable to generate predicted values separately from each of the subsamples (Davidson and MacKinnon, 1993, p. 379).[4] Durbin-Wu-Hausman tests lead to rejection of the null in both subsamples: before the agreement, $\chi^2_{(1)}$=6.251, p-value=0.012; and during the agreement, $\chi^2_{(1)}$=6.847, p-value=0.009. Denoting the instruments from the two subsamples as $\mathbf{W}_1$ and $\mathbf{W}_2$, the null and alternative hypotheses underlying (4) can be stated as

$$(5)\qquad H_0:\ [\boldsymbol{\beta}_1 \mid \sigma_1^2] = [\boldsymbol{\beta}_2 \mid \sigma_2^2] \text{ conditional on } \mathbf{W}$$

$$H_A:\ [\boldsymbol{\beta}_1 \mid \sigma_1^2] \neq [\boldsymbol{\beta}_2 \mid \sigma_2^2] \text{ conditional on } \mathbf{W}_1 \text{ and} \mathbf{W}_2$$

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[4] Although Davidson and MacKinnon (1993) develop an LM test for testing structural change based on instrumental variable estimates, we cannot employ their test because it is predicated on equal variances across regimes.

where the instruments used to estimate the model under the null and the alternative differ and all subscripts correspond to subsamples partitioned by $T_1$ and $T_2$. A likelihood ratio test based on these conditional estimates leads to rejection of the null hypothesis in (5) ($\chi^2_{(8)}$=50.487, p-value=0.00000). Hence, there is relatively strong evidence to indicate a distinct supply-response regime for Florida fresh tomato shipments once the suspension agreement was implemented.

### *Deterministic Switching Based on Other Variables*

Some observers have suggested Florida grower-shippers might attempt to ship more tomatoes as the Nogales f.o.b. price approaches the reference price, in an effort to drive prices low enough to make the reference price binding, thereby causing the suspension of shipments in the following week. For simplicity, we will refer to the potential for this kind of response as "opportunistic" behavior. In order to assess the validity of this contention about opportunistic behavior, we need to ascertain whether supply response changes as Nogales f.o.b. prices decline to levels near the reference price. Here we look for evidence of a separate regime but we have no precise notion of when such a regime change might have occurred. Hence, a deterministic switching model based on other variables, namely, the proximity or "nearness" of Nogales f.o.b. price to the reference price, is investigated in what follows. Bear in mind that we will assume the subsample prior to implementation of the suspension agreement, $T_1$, belongs to a different regime. As such, the search for evidence of opportunistic behavior is restricted to the period of the suspension agreement.

Goldfeld and Quandt originally proposed a deterministic switching model based on variables other than time which they deemed the D-method (Goldfeld and Quandt, 1973b). Without loss of generality, consider two regimes where an indicator variable, $D_t$, is used to choose which observation belongs in which regime. The observed outcomes are a function of other variables, $\mathbf{Z}_t$, and parameters, $\pi$, according to the following rule

$$\begin{aligned} D_t &= 0 \;\; if \;\; \mathbf{Z}_t\boldsymbol{\pi} \le 0 \\ D_t &= 1 \;\; if \;\; \mathbf{Z}_t\boldsymbol{\pi} > 0 \end{aligned} \qquad t = 1,\ldots,T \tag{6}$$

Given this decision rule for cataloging observations, the log likelihood to be maximized is

$$\ln L = -\frac{T}{2}\ln 2\pi - 0.5\sum_{t=1}^{T}\ln\left[\sigma_1^2(1-D_t)^2 + \sigma_2^2 D_t^2\right] - 0.5\sum_{t=1}^{T}\frac{\left(y_t - \mathbf{X}_t\left[\boldsymbol{\beta}_1(1-D_t)+\boldsymbol{\beta}_2 D_t\right]\right)^2}{\sigma_1^2(1-D_t)^2 + \sigma_2^2 D} \tag{7}$$

Maximization of (7) with dichotomous variables would require assessing the various combinations of $D_t$ which for large samples could be prohibitively costly. To make estimation tractable, Goldfeld and Quandt (1973a) suggest using a probit model for (6) to approximate values of $D_t$ . Lee, Maddala, and Trost have developed a two-stage estimation procedure to use for maximizing (7) when instrumental variable estimators are required. Lee and Yang have implemented the procedure in the context of simultaneous-equation of finance and investment decisions.

The difficulty with adapting (7) to the present problem is that we simply do not observe an indicator variable such as $D_t$ which could be employed in estimating the switching regime model based on other variables. In fact, whether any given observation belongs to one regime or another is precisely what we seek to determine. Therefore, we propose a variant of (7) in which a grid search over plausible values of $\pi$ is performed to look for evidence of a regime change.

The contention concerning opportunistic behavior can be translated into the following decision rule for cataloging observations

$$\begin{aligned} D_t &= 0 \;\; if \;\; p_{Nog,t} - p_{ref} > \delta \\ D_t &= 1 \;\; if \;\; p_{Nog,t} - p_{ref} \le \delta \end{aligned} \qquad t = 1,\ldots,T \tag{8}$$

where $p_{Nog,t}$ is the Nogales f.o.b. price in week *t*, $p_{ref}$ is the reference price established by the Department of Commerce, and δ is the proximity or "nearness" parameter to be varied in the grid search. To make estimation tractable, we employ the probit specification so that $D_t$ values are confined inclusively to the zero-one interval. The resulting switching regime model is a composite of deterministic switching based on time *and* other variables. The composite log likelihood is

$$\ln L = -\frac{T}{2}\ln 2\pi - 0.5\sum_{t\in T_1}\ln\sigma_1^2 - 0.5\sum_{t\in T_1}\frac{(y_t - \mathbf{X}_t\boldsymbol{\beta}_1)^2}{\sigma_1^2} \qquad (9)$$

$$-0.5\sum_{t\in T_2}\ln\left[\sigma_2^2(1-D_t)^2 + \sigma_3^2 D_t^2\right] - 0.5\sum_{t\in T_2}\frac{(y_t - \mathbf{X}_t[\boldsymbol{\beta}_2(1-D_t) + \boldsymbol{\beta}_3 D_t])^2}{\sigma_2^2(1-D_t)^2 + \sigma_3^2 D}$$

in which $D_t = \Phi(p_{Nog,t} - p_{ref} - \delta)$ and Φ denotes the cumulative distribution function of the standard normal. The composite model (9) allows for the possibility of three distinct regimes in which $\boldsymbol{\beta}_1$ and $\sigma_1$ correspond to the period before the suspension agreement, $\boldsymbol{\beta}_2$ , $\boldsymbol{\beta}_3$, $\sigma_2$, and $\sigma_3$, correspond to the suspension agreement period, and $[\boldsymbol{\beta}_2 | \sigma_2]$ can possibly differ from $[\boldsymbol{\beta}_3 | \sigma_3]$ if supply response differs for f.o.b. prices close to the reference price. The grid search entails collecting the ln *L* values as $\delta$ is varied over plausible values. A plot of ln *L* vs. $\delta$ may reveal whether there are measurably distinct regime changes as Nogales f.o.b. prices near the reference price (Quandt).[5] In the grid search, we use *PNVIN56L*, the low f.o.b. price reported for 5 x 6 vine ripe tomatoes at Nogales

Figure 3a depicts the log likelihood ratio for the composite model over all possible values of δ. As is typical with such graphs, the log likelihood is not a smooth, monotonic function. The subsample for which the parameters $[\boldsymbol{\beta}_3 | \sigma_3]$ are estimated, $T_3$, varies as δ changes, from 29

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[5] Quandt also proposed a likelihood ratio test for deterministic switching according to time but the test statistic is not distributed $\chi^2$ under the null hypothesis.

observations at δ=\$0.01 to 120 observations at δ=\$14.00. The corresponding subsample sizes for estimating [$\boldsymbol{\beta}_2$| $\sigma_2$] are equal to $T_2 \equiv 174 - T_3$. Because the Nogales f.o.b. prices do not take all possible values between the reference price and the highest f.o.b. price, small changes in δ do not always yield changes in subsample size. Figure 3a is simply a diagnostic tool; it does not provide a formal test. As such, the diagnostic results are inconclusive: the single largest change in the log likelihood values occurs when the proximity parameter changes between \$5.50 and \$6.00 per carton, and the log likelihood tends to flatten for values of δ in excess of \$6.00. But there are several local maxima occurring at \$0.04, \$0.75, and \$3.50 per carton.

The particular parameter of interest in this composite switching regime model is that associated with own Florida price. In order to assess the sensitivity of the own-price effect as the Nogales f.o.b. prices changes with respect to the reference price, we plot own-price coefficient values from $\boldsymbol{\beta}_3$ as a function of δ in Figure 3b (Brown et al. ). The own-price coefficient varies substantially over the range of δ values but we are unable to judge whether those values are different from zero because we have yet to obtain consistent estimates of the standard errors. The only standard errors available are those conditional on a fixed value of δ. Taking those standard errors with the necessary precaution, it appears the most precise own-price effects occur for Nogales f.o.b. prices near the reference price:

| δ | Own-Price Coefficient | p-value |
|---|---|---|
| 0.005 | 9,617.0 | 0.011 |
| 0.02 | 8,045.4 | 0.037 |
| 0.04 | 6,494.3 | 0.041 |

For $\delta > \$0.08$, all p-values on the own-price coefficients exceed 0.100, providing very tentative evidence of imprecise own-price estimates. Of course, more work must be done to obtain consistent estimates of the asymptotic covariance matrix of the estimated parameters.

### Other Parameter Estimates

Parameter estimates for the composite deterministic switching model are presented in table 2. Because the p-values are based on inconsistent estimates of the asymptotic standard errors, only a cursory discussion of the parameter estimates follows. Own-price effects before the suspension agreement and during the suspension agreement when the reference price is not binding appear indistinguishable from zero. This result is unexpected insofar as the single-regime model with no switching results in a statistically significant, positive own-price effect. Given the proxy nature of the *WAGE* variable, it is perhaps not surprising that its coefficients do not appear to differ from zero. The available planted acreages by regions appear to have effects of reasonable magnitude when they are conditionally different from zero. For example, the value of 2.02 for *AVACRE_PR* indicates that an additional available acre of tomatoes planted in the Palmetto-Ruskin area would add an additional 2,020 lbs. to the quantity supplied. The Palmetto-Ruskin region tends to supply its largest quantities at the beginning and end of the season, so an additional available acre from this area appears to have the most pronounced effect on quantities supplied. Finally, as is consistent with the composite deterministic switching specification, the estimated variances of each regime, $\sigma^2$, suggest that a homoskedastic model over the entire sample period would not be appropriate.

One final comment regarding the effects of planted acreage on supply response should be made. Acreage is typically conceived of as a quasi-fixed factor of production, which in the longer run can clearly be changed. In the present context, the effects of available acreage planted differ in an important way. The growing degree days, which determine the timing and duration of potential harvest, are a function of strictly exogenous events: day length and daily temperature. For field-grown crops, these events are clearly beyond the control of the grower-shipper. Of course, acreages planted in any given week could be modified in the longer run to affect the distribution of quantities supplied during the season. Hence, the available acreage variables reflect a combination of exogenous events and decisions made by firms.

## Summary and Conclusions

The suspension agreement implemented by the U.S. Department of Commerce in November 1996 instituted a “reference” price on imports of fresh tomatoes from Mexico. The trigger price curtails exports of fresh tomatoes from Mexico in a given week if f.o.b. prices in the previous week fall as low as the reference price. Using weekly data on Florida shipments of round tomatoes and weekly plantings in the four major production areas of Florida, a supply-response model is specified to assess changes in shipment behavior with the implementation of the suspension agreement.

An innovative feature of the supply-response model is the inclusion of available weekly planted acreages based on growing degree days. The relevant lags for planted acreage are determined based on actual growing conditions, which results in variable lag lengths within any growing season rather than an arbitrary fixed lag length for all growing seasons. In particular, location-specific minimum and maximum temperatures are used to construct growing degree day measures which give predictions of initial harvest date and potential duration of harvest.

In order to investigate the potential for changes in Florida shipment behavior, a composite deterministic switching model is employed. Because tests for weak exogeneity rejected the null, an instrumental variable version of the deterministic model is estimated. The model contains three regimes. The first regime, based on the known switch point (November 1, 1996), encompasses the three seasons in the sample before the suspension agreement was implemented. The other two regimes correspond to the five seasons in the sample when the suspension agreement was in effect. These latter two regimes are distinguished by when Nogales f.o.b. prices neared the reference price: one regime occurs when Nogales f.o.b. prices are "near" the reference price; the other occurs when prices are not near the reference price. Initial parameter estimates suggest Florida shipments of round tomatoes were more responsive to own-price changes when the Nogales f.o.b. price is near the reference price.

The econometric results presented here are subject to several limitations at this point. Future work in refining the econometric estimates should include obtaining consistent estimates of the asymptotic covariance matrix of the parameters so that statistical inferences regarding price responses can be made. Unfortunately, lack of data on weekly plantings after 2001 precludes in further augmentation of the sample to more recent periods. Regime changes based on other deterministic or stochastic approaches should also be pursued. Tests for serial correlation should also be performed.

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**Figure 1. Average Acres Planted, 1997/98 – 2000/01.**

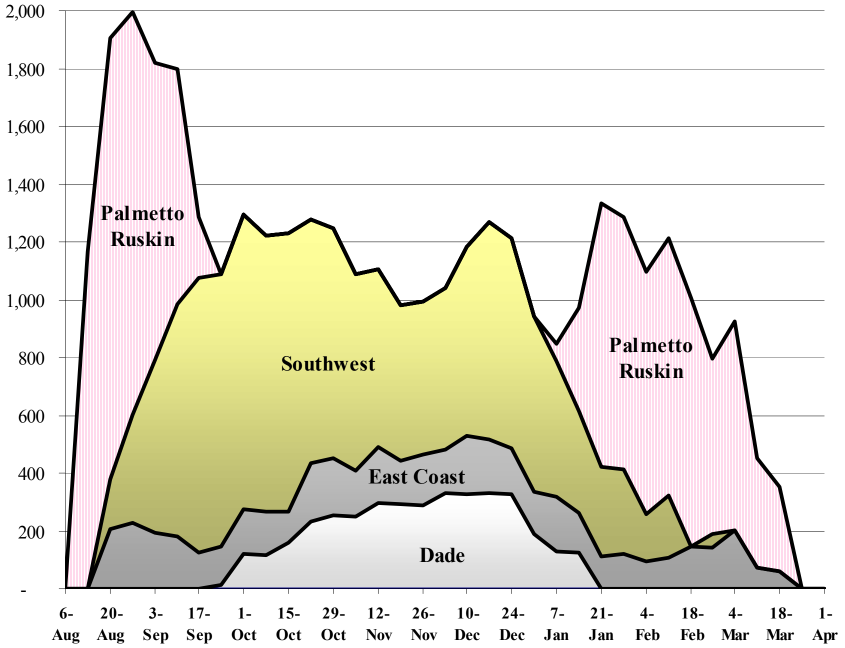
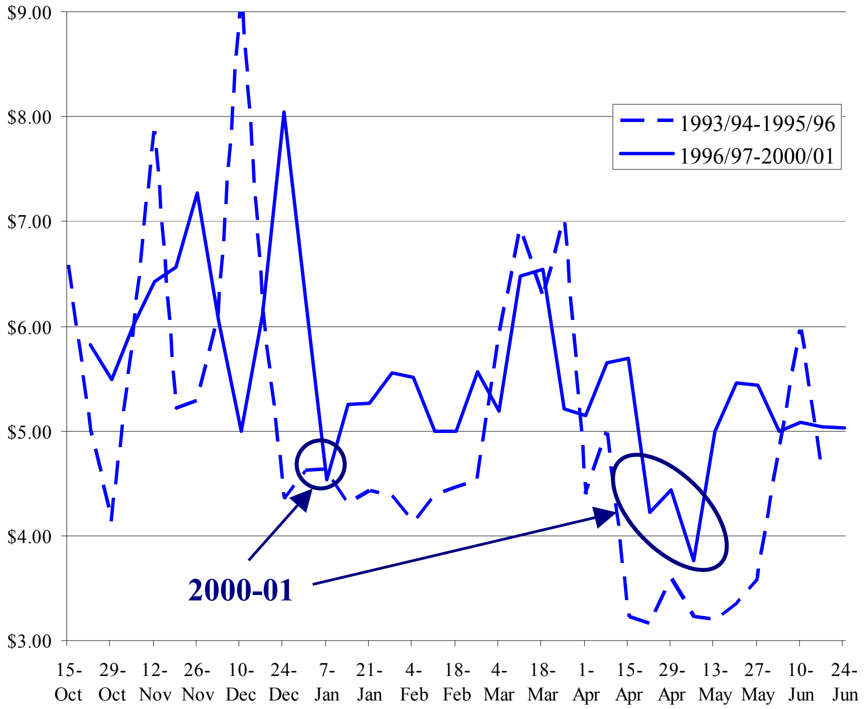
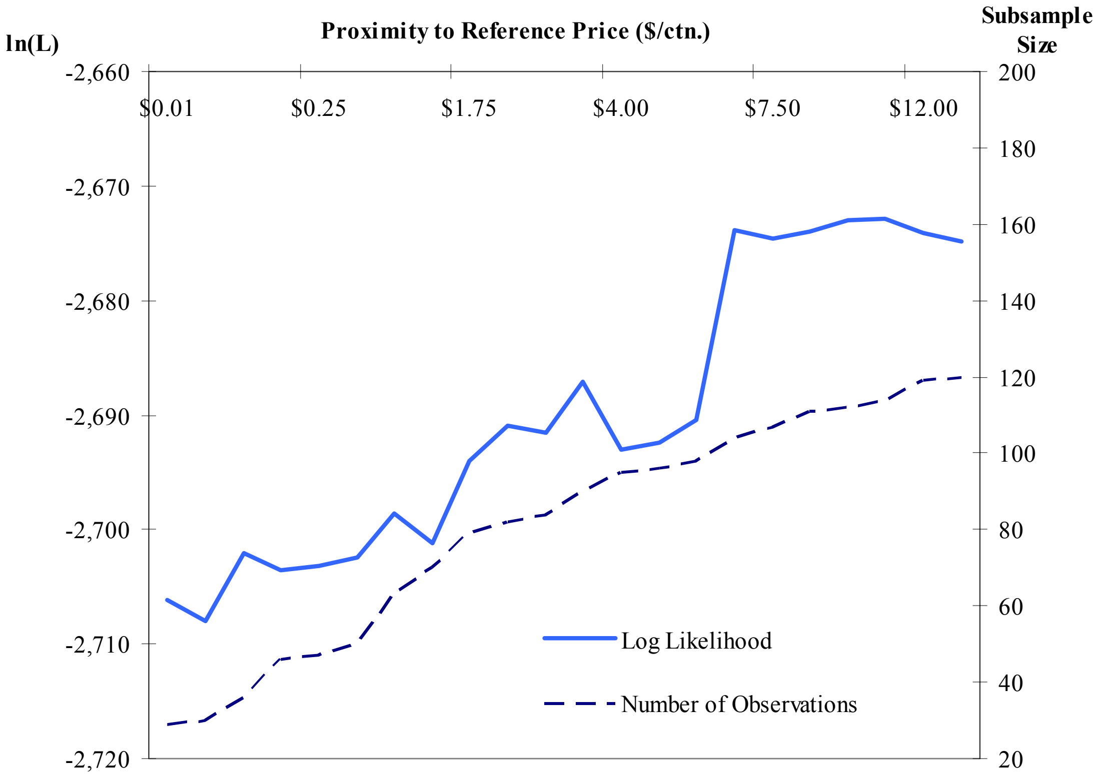


**Figure 2. Minimum Weekly Mature Green f.o.b. Price, Florida.**



Note: These are the minimum prices for a given week in the respective seasons, not the averages of the minimum prices for a given week.

## Figure 3a. Switch Point with Proximity to Reference Price: ln*L* and Subsample Size



## Figure 3b. Switch Point with Proximity to Reference Price: Own-Price Effect

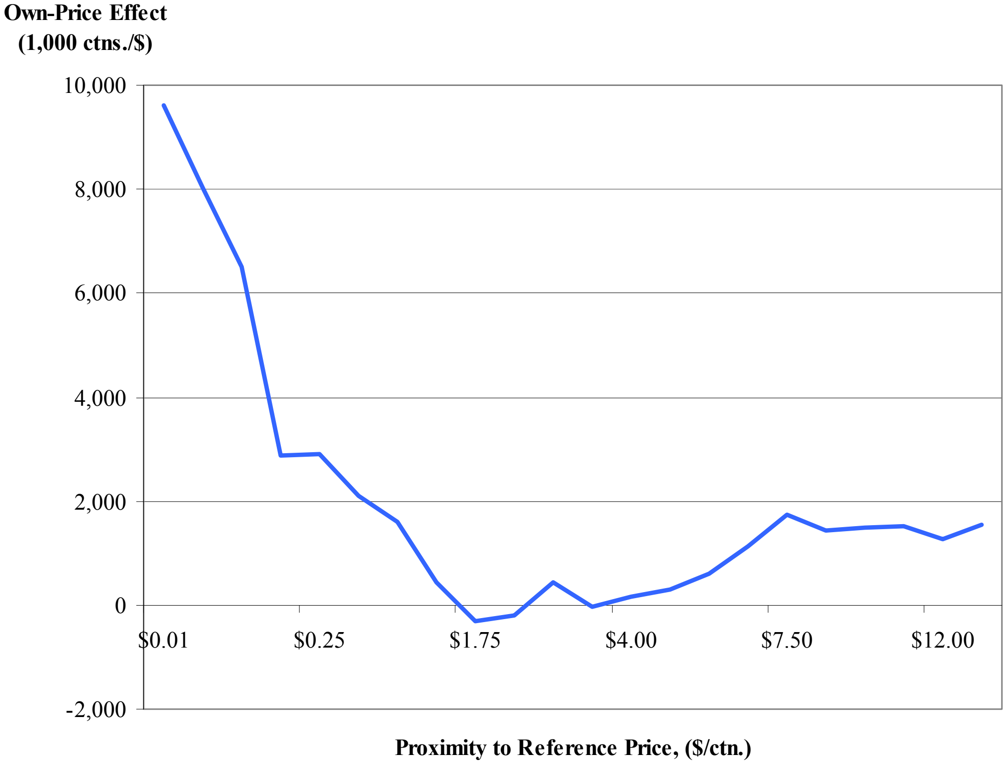


**Table 1. Descriptive Statistics, Before and During the Suspension Agreement.**

| Variable | Definition | Units of Measure | Mean Values<br>Before Suspension Agreement (1993/94 – 1995/96) | First Reference Price (1996/97 – 1997/98) | Second Reference Price (1998/99 – 2000/01) |
|---|---|---|---|---|---|
| *QFROUND* | Florida Round Tomato Quantity[a] | 1,000 lbs. | 29,634 | 37,251 | 41,342 |
| *PFRNDALLMAT* | Weighted Average Florida Mature Green & Vine Ripe Price | $/25 lb. Ctn | 8.18 | 8.91 | 8.10 |
| *QNVINERIPE* | Nogales Vine Ripe Quantity | 1,000 lbs. | 25,095 | 27,905 | 15,653 |
| *PNVIN55L* | Nogales Vine Ripe f.o.b. Low Price, 5 x 5 | $/25 lb. Ctn | 4.60 | 5.46 | 5.09 |
| *PNVIN55H* | Nogales Vine Ripe f.o.b. High Price, 5 x 5 | $/25 lb. Ctn | 6.79 | 6.50 | 6.55 |
| *PNVIN56L* | Nogales Vine Ripe f.o.b. Low Price, 5 x 6 | $/25 lb. Ctn | 3.89 | 5.02 | 4.61 |
| *PNVIN56H* | Nogales Vine Ripe f.o.b. High Price, 5 x 6 | $/25 lb. Ctn | 5.87 | 5.91 | 5.95 |
| *GDD1_DD* | Growing Degree Days, Dade[b] | Degrees F. | 9,969 | 7,785 | 7,122 |
| *GDD1_EC* | Growing Degree Days, East Coast | Degrees F. | 15,528 | 13,511 | 13,489 |
| *GDD1_SW* | Growing Degree Days, Southwest | Degrees F. | 14,749 | 13,048 | 14,264 |
| *GDD1_PR* | Growing Degree Days, Palmetto-Ruskin | Degrees F. | 7,014 | 6,115 | 5,708 |
| *AVACRE_DD* | Available Acres, Dade | Acres | 1,329 | 953 | 1,064 |
| *AVACRE_EC* | Available Acres, East Coast | Acres | 1,392 | 1,136 | 1,181 |
| *AVACRE_SW* | Available Acres, Southwest | Acres | 6,098 | 4,330 | 5,340 |
| *AVACRE_PR* | Available Acres, Palmetto-Ruskin | Acres | 2,532 | 2,241 | 2,297 |
| *WAGE* | Florida Average Hourly Earnings | $/Hour | 9.688 | 10.005 | 10.832 |
|  | Number of Observations |  | 101 | 68 | 106 |

[a] All observations are weekly.

[b] Growing degree days are the *sum* of daily values. Hence, their values may appear large for being measured in degrees Fahrenheit.

**Table 2. Limited Information Parameter Estimates**

| | Pre-Suspension | | Suspension, Nogales Price not Close | | Suspension, Nogales Price Close | |
|---|---|---|---|---|---|---|
| | Coefficient | p-value | Coefficient | p-value | Coefficient | p-value |
| Constant | -39,820 | 0.667 | 15,534 | 0.692 | -121,036 | 0.255 |
| Own-Price | -495 | 0.567 | 1,511 | 0.288 | 9,617 | **0.011** |
| *WAGE* | 7,368 | 0.434 | 787 | 0.810 | 8,333 | 0.307 |
| *AVACRE*_DD | -0.87 | 0.652 | -4.61 | 0.196 | -0.43 | 0.905 |
| *AVACRE*_EC | 1.36 | 0.775 | -3.92 | 0.468 | -6.04 | 0.423 |
| *AVACRE*_SW | -0.63 | 0.393 | 1.41 | 0.186 | -0.88 | 0.716 |
| *AVACRE*_PR | 2.02 | **0.013** | 1.62 | 0.151 | 5.77 | **0.002** |
| $\sigma^2$ | 93,663,800 | **0.000** | 203,211,000 | **0.000** | 42,899,000 | **0.000** |

Note: $\delta$ = \$0.005/ctn.

## Weather Data Appendix

Daily weather observations on minimum and maximum temperature (TMIN and TMAX) as well as precipitation (PRCP) were extracted from the *The Global Daily Climatology Network (GDCN)* compact disks and the *Global Surface Summary of Day* (*GSOD*) website. The *GDCN* dataset is comprised of about 32,000 weather stations throughout the world. The time period for which daily observations are available at each station varies considerably but no data are recorded after 2000. The (*GSOD*) website contains daily weather observations from 1994 to the present for over 8,000 weather stations around the world. In order to construct a continuous series of data from 1990 through 2001, both *GDCN* and *GSOD* series were used. Not all weather stations in *GSOD* are available in *GDCN* so matching stations across the two sources is not possible in some cases.

The stations chosen for Florida production regions were chosen based on two criteria: (i) proximity to production region and (ii) availability of continuous daily observations during the period of analysis. The stations chosen for analysis are listed in Tables A.1 and A.2.

Not all stations have continuous series of daily observations. Missing daily observations occur in two ways: (i) for extended periods of a month or longer; and (ii) intermittently. When longer gaps in the data appear, some method for filling in observations was used.

### Florida Weather Stations

Florida weather stations were chosen to correspond to the four main tomato production areas: Dade, East Coast, Southwest, and Palmetto-Ruskin. Three stations—Miami, West Palm Beach, and Tampa—displayed continuous daily observations without extended gaps or intermittent missing observations.

Although Homestead stations would have been preferred because of their proximity to most Dade County production areas, major gaps in available daily observations in *GDCN* data precluded their use.

For East Coast and Palmetto-Ruskin regions, other stations could have been used, but the two *GDCN* airport stations in West Palm Beach and Tampa had no missing observations for eleven consecutive years.

In southwest Florida, no single station has a continuously available sample of daily observations. Because of its proximity to southwest production areas, we take the Immokalee station as the base station and fill in missing gaps with data from either the Naples or the La Belle station. The Ft. Myers station has a continuous gap of two years' missing data so we chose not to use its observations. Where possible, we chose to fill missing Immokalee observations with those from Naples because temperatures are more highly correlated between Immokalee and Naples stations than between Immokalee and La Belle stations (see Table A.3).

*GSOD* contains three airport weather stations which match nearly identically the *GDCN* stations for Miami, West Palm Beach, and Tampa. However, *GSOD* contains no direct matches for Immokalee (lat. 26.45N, lon. 81.43W). The closest *GSOD* station is Southwest Florida International airport (lat. 26.53N, lon. 81.75W). Stations in Fort Myers and Naples are also close but correlation coefficients for TMIN and TMAX between Immokalee and Southwest Florida International airport were the highest.

**Units of Measure**

The *GDCN* series uses metric units whereas the *GSOD* uses English units. We converted all series to like measures: TMIN and TMAX are expressed in degrees Fahrenheit while PRCP is measured in inches.

## Day Length

Daily day length measured in hours at each of the production areas was calculated from sunrise and sunset times available from the U.S. Naval Observatory.

### Table A.1 GDCN Data Description

| Area | Station ID | Station Name | Range of Data | Major Gaps in Data | # of Months |
|---|---|---|---|---|---|
| Dade | 42500085663 | MIAMI WSCMO AIRPORT | 1990 -2000 | None | 132 |
| | 42500084095 | HOMESTEAD GEN AVIATION AP | June1990 - 2000 | Aug. 1992 - Oct. 1995 | 88 |
| | 42500084091 | HOMESTEAD EXP STN | June1990 - 2000 | Aug. 1992 - Oct. 1995 | 88 |
| East Coast | 42500089525 | WEST PALM BEACH INT AP | 1990 -2000 | None | 132 |
| S.W. FL | 42500084210 | IMMOKALEE 3 NNW | 1990 - Mar. 1999 | July-Sept 1995 | 108 |
| | 42500083186 | FORT MYERS FAA/AP | 1990 -2000 | Dec. 1990; 1996-1997 | 102 |
| | 42500086078 | NAPLES | 1999 - 2000 | Sept.1992, Jul.-Aug. 1995, Feb. 2000 | 128 |
| | 42500080887 | BONITA SPRINGS 2 MI ESE | Null | | 0 |
| | 42500084662 | LA BELLE | 1990 - Sept. 2000 | Nov.-Dec.1993; Dec.1994 | 125 |
| Palmetto-Ruskin | 42500088788 | TAMPA WSCMO ARPT | 1990 -2000 | None | 132 |

### Table A.2 GSOD Data Description

| Area | Station ID | Station Name | Range of Data | Major Gaps in Data | # of Months |
|---|---|---|---|---|---|
| Dade | 722020 | MIAMI INTL AP | 1994 - present | None | 132 |
| East Coast | 722030 | WEST PALM BEACH INT | 1994 - present | None | 132 |
| S.W. FL | 722108 | SOUTHWEST FLORIDA I | 1994 - present | July-Sept 1995 | 108 |
| Palmetto-Ruskin | 722110 | TAMPA INTERNATIONAL | 1994 - present | None | 132 |