The Market for Winter Tomatoes: A Rational Expectations Interpretations
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by

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The Florida Agricultural Market Research Center

A Service of
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Institute of Food and Agricultural Sciences

The purpose of this Center is to provide timely, applied research on current and emerging marketing problems affecting Florida's agricultural and marine industries. The Center seeks to provide research and information to production, marketing, and processing firms, groups and organizations concerned with improving and expanding markets for Florida agricultural and marine products.

The Center is staffed by a basic group of economists trained in agriculture and marketing. In addition, cooperating personnel from other IFAS units provide a wide range of expertise which can be applied as determined by the requirements of individual projects.
Florida produces about 90 percent of domestic fresh tomato supplies during the November to mid-June season. Since the Cuban trade embargo of February 1962, Mexico has become the major foreign supplier of fresh winter tomatoes. The fresh winter tomato market in the U.S. has been almost equally shared by Florida and Mexico in recent years. The rivalry for this market reached the point in 1979 that Florida growers charged that Mexican producers were dumping their product on the U.S. market. Many Florida growers suggest that unless Mexican tomato imports are limited the Florida tomato industry will effectively disappear.

Primary attention in this paper is focused on domestic tomato acreage allocations in light of the increasing Mexican influence on the winter tomato market. The paper does not attempt to evaluate the welfare effects of Mexican imports on the Florida tomato industry. In addition to the emphasis on acreage response, the domestic quantity and price effects are also considered.

Most efforts to explain acreage devoted to agricultural crops utilize some variant of a cobweb model since the ultimate price of the crop cannot be ascertained until the completion of the production cycle. Nevertheless, if our supply and demand framework is truly representative of the way the market works, an alternative to lagged price for representing the anticipated price for the crop is the price—
prediction of the supply and demand model itself. Thus, acreage would be argued to be dependent on the expected price of the crop; and expected price would be quite simply the solution of the supply and demand model for price on the basis of information available at planting time. The underlying hypothesis is that producers are acting in accordance with the information available to them at planting time and in a way represented by the interaction in the supply and demand model. Viewed in this way, planted acreage decisions would be based on such factors as anticipated Mexican imports and their attendant effect on the price of tomatoes. One distinction between this and the traditional cobweb framework is that in the latter case lagged imports may influence planted acreage via their effect on lagged prices, but any impact expected imports might have on current price is ignored in the acreage relationship. Additionally, by utilizing the expected price to explain acreage, all information in the supply and demand model including expected imports is brought to bear to assist in explaining acreage. This concept is referred to in the economics literature as the rational expectations hypothesis as introduced by Muth.\textsuperscript{1}

An economic model of the winter tomato market incorporating the rational expectations hypothesis is specified in the following section. This is followed by a discussion of alternative price expectation hypotheses. The parameters of the supply and demand model are then estimated for the rational expectations and the cobweb models. The final section of the paper presents an evaluation of the results and assesses their implications.
Model Specification

We specify a supply and demand model for Florida tomatoes since Florida produces nearly all of the domestic winter fresh tomatoes. The demand equation is an aggregate U.S. demand function. The supply side is decomposed into an acreage equation and a yield equation. The rationale for the latter is that the decision to plant must be made considerably before the market time. Nevertheless, a number of factors can alter the yield once acreage is devoted to tomatoes.

The structural model is specified by the following four equation system with all variables in logarithms:

\[
\begin{align*}
(1) & \quad A_t = \alpha_0 + \alpha_1 P_t^* + \alpha_2 C_t^* + \alpha_3 R_t + \alpha_4 A_{t-1} + \nu_{1t} \\
(2) & \quad Y_t = \beta_0 + \beta_1 P_t - \beta_2 L_t + \beta_3 W_t + \beta_4 X_t + \nu_{2t} \\
(3) & \quad Q_t = \gamma_0 + \gamma_1 P_t - \gamma_2 D_t + \gamma_3 M_t + \gamma_4 I_t + \nu_{3t} \\
(4) & \quad Q_t = A_t + Y_t
\end{align*}
\]

where

\begin{align*}
A_t & = \text{acreage of tomatoes planted; } \\
P_t^* & = \text{expected price per carton of tomatoes; } \\
C_t^* & = \text{expected cost of a carton of tomatoes; } \\
R_t & = \text{prime interest rate prevailing during the time planting decisions are made (July through January); } \\
Y_t & = \text{yield of 20 pound cartons per planted acre; } \\
P_t & = \text{season average price per carton of tomatoes; }
\end{align*}
\[ L_t = \text{hourly wage of piece-rate farm workers in Florida (mid-season)}; \]

\[ W_t = \text{weather index constructed from the detrended yields of cucumbers and green peppers - two vegetable crops grown in many of the same areas as tomatoes during the winter season}; \]

\[ X_t = \text{adoption of plastic mulch: - 0 prior to 1973 season; - 1 thereafter}; \]

\[ Q_t = \text{quantity of tomatoes shipped}; \]

\[ D_t = \text{U.S. personal consumption expenditures price deflator (October through June)}; \]

\[ M_t = \text{quantity of Mexican tomatoes imported (October through June)}; \]

\[ I_t = \text{U.S. total real disposable income (October through June)}. \]

Since product prices and production costs are uncertain at the time the acreage decision is made, we argue that decisions are made on expected price and expected cost. The specification of expectations is treated in the following section. Much of the land used to grow tomatoes is rented. Consequently, the tomato grower may be less interested in the production of other crops than in the opportunity cost of funds used on purchased inputs, as reflected by the prime rate \( R_t \). Finally, the producer may not be able to fully adjust acreage to an optimum level due to mistakes or increased costs, thus he can only make a partial adjustment as reflected by the inclusion of \( A_{t-1}^{2/3} \).

Tomato yields \( Y_t \) are strongly influenced by the number of times the crop is harvested. Because tomatoes do not mature uniformly, fields of staked tomatoes may be picked five times and ground plants may be
picked twice depending on crop and market conditions (Zepp and Simmons). The harvesting decision is argued to depend on current product price (the price is known at harvest time in contrast to the acreage question) and the wage rate. Furthermore, the specification assumes that it is the ratio of price to wage rate that is important. They thus have the same coefficient except for sign. Tomato yields are also highly affected by cold weather which can either destroy the plant or inhibit the fruit from setting. The introduction of full-bed plastic mulch during the 1970s represented an important change in technology as reflected through an increase in yields.

The demand for tomatoes \( (Q_p) \) is specified at the wholesale level including the usual economic variables, deflated price and deflated disposable income. In addition, Mexican imports are included as a demand shifter for Florida tomatoes.\(^3\) The final equation (4) closes the system with the identity that quantity demanded is equal to yield per acre times the number of acres planted.

**Modeling Expectations**

Two expectational variables are utilized in our supply response model, both of which occur in the acreage equation. These are expected price and expected cost of production, neither of which can be known at the time the crop is planted. Typically \textit{ad hoc} extrapolative models for expectation variables of the form

\[
Z^* = \sum \lambda_{i} Z_{t-i}
\]
are used. The number of lags and the types of restrictions to put on the $\lambda_i$ are usually subjectively determined. Moreover, such procedures ignore the information specified in the structural model for how prices are determined in the market. Nerlove has recently argued that supply response models have not become more "econometrically relevant" since his work of over two decades ago. Shonkwiler similarly comments that:

A fundamental difficulty with such expectation formation models concerns their arbitrariness and lack of theoretical basis. These models are not necessarily accurate representations of economic behavior implied by the underlying economic structure.

The rational expectations model presented in this paper is offered as an alternative to the traditional agricultural supply response approaches.

Despite Muth's original casting of the rational expectations model in terms of market supply and demand relations, empirical applications of the rational expectations hypothesis (REH) have almost exclusively appeared in the macroeconomics province (vid. Shiller's review). In the agricultural sector where fixed biological lags separate the production decision and consequent output, supply response models have typically employed extrapolative mechanisms to represent expected prices or returns (c.f. Aaskari and Cummings, Nerlove). By contrast, the REH maintains that participants in the market act as if they were solving the supply and demand system in forming their price expectations. Thus, the rational expectations model and models incorporating extrapolative types of expectations are two competing frameworks for explaining acreage variations.
There are several reasons to expect that Florida tomato growers form rational expectations. Note first that production is found in a small geographic area which implies that producers face similar economic and climatic environments. The highly commercial and concentrated nature of the Florida tomato industry may produce a situation more conducive to the use of rational expectations by producers (DeCanio). Finally, the intense competition with Mexican imports and the information collection and dissemination service of the Florida Tomato Committee suggest that growers take important supply and demand forces into account when making production decisions.

In its most general form, the rational expectations interpretation of expected price, $P^*_t$ is the mathematical expectation of $r_t$ given all information available when the expectation is formed. In a structural economic model this information consists of the predetermined variables and the model's reduced form parameters (Wallis). Specifically, the econometric model presented in equations (1)-(4) yields the following reduced form equation for the price variable:

$$
\begin{align*}
\alpha_1^*P_t + \beta_1^*P + \gamma_1^*P &= -\alpha_0^* - \alpha_2^*C_t^* - \alpha_3^*A_t - \alpha_4^*t - \beta_0^* + \beta_1^*t \\
&\quad - \beta_2^*W_t - \beta_3^*X_t + \gamma_0^* - \gamma_1^*D_t + \gamma_2^*M_t + \gamma_3^*I_t
\end{align*}
$$

Taking the expectation of the above equation, the expected price, $P^*_t$, is given by

$$
\begin{align*}
P^*_t &= (\alpha_1^* + \beta_1^* - \gamma_1^*)^{-1}(-\alpha_0^* - \alpha_2^*C_t^* - \alpha_3^*X_t - \alpha_4^*t - \beta_0^* + \beta_1^*t \\
&\quad - \beta_2^*W_t - \beta_3^*X_t + \gamma_0^* - \gamma_1^*D_t^* + \gamma_2^*M_t^* + \gamma_3^*I_t^*)
\end{align*}
$$

where asterisks on the right-hand-side of (7) denote the expectations of the current exogenous variables.
The consequences of expression (7) are immediate since it explicitly shows that expected price depends not only upon expected levels of imports but also upon the other predetermined variables or forecasted exogenous variables in the system. And, this dependence is given exactly as a function of the structural model's parameters.

The values of the exogenous variables are forecasted by the following relations:

\[
Z_{lt} = \delta_{l0} + \delta_{l1} Z_{l,t-1} + \epsilon_{lt}
\]

since there is no other structural information concerning their generation (Wallis). The exception to (8) occurs for the weather index which is created with zero mean. Because this variable is not expected to have any systematic component, we assume that its forecasted value is identical to its mean value.

The alternative cobweb model is specified by substituting \( P_{t-1} \) for \( P_{t}^* \) in the acreage equation (1). The model is dynamic since lagged acreage is included as an explanatory variable. This particular form for acreage response models has been found to explain tomato acreage fairly well (Morris).

**Estimation Results**

The data used are the nineteen winter seasons from 1961-62 through 1979-80. Under the REH the variables exogenous to the system, \( C_t^*, L_t^*, D_t^*, M_t^* \) and \( I_t^* \), were predicted using (8) and had squared correlations with their actual values of .80, .98, .996, .80, and .994.
respectively. Substituting these predicted series in (7) gives an expression for $P_t^*$ which is linear in the variables but non-linear in terms of the structural parameters. Estimation of the four equation system (1)-(4) is accomplished by replacing $P_t^*$ in (1) with expression (7). The resulting acreage equation under the REH is then:

$$
A_t = a_0 + \frac{a_1}{a_1 + b_1 - \gamma_1} \left[ -a_0 - a_2 X_t - a_3 Y_t - a_4 A_{t-1} \\
- b_0 + b_1 Y_t - b_2 X_t - b_3 Y_t + \gamma_2 X_t + \gamma_3 Y_t + \gamma_4 Y_t \\
+ a_2 C_t + a_3 R + a_4 A_{t-1} + \epsilon_t \right]
$$

Under the alternative of a dynamic cobweb model the acreage equation appears as

$$
A_t = a_0 + a_1 P_{t-1} + a_2 X_t + a_3 Y_t + a_4 A_{t-1} + \mu_t
$$

Under the REH the system is highly non-linear in the parameters in addition to having parameter restrictions across equations. Although limited information methods such as two stage least squares could be utilized to estimate the parameters equation by equation, the occurrence of cross-equation parameter restrictions make this much less attractive than usual. A particularly appropriate method for this simultaneous equations model is full information maximum likelihood (although still conditional on the forecasts of $C_t^*$, $L_t^*$, $D_t^*$, $M_t^*$ and $I_t^*$). The disturbances $\mu_{1t}$, $\mu_{2t}$, $\mu_{3t}$ as well as $\mu_{1t}'$, $\mu_{2t}'$, $\mu_{3t}'$ are assumed to follow joint normal distributions.

The maximum likelihood parameter estimates for both expectations models are presented in Table 1. Note that the parameters may also be interpreted as elasticities since all variables are in logarithmic
form. It is apparent that the REH "fits" the data better than the cobweb hypothesis since its calculated likelihood is greater. In fact using a test suggested by Revankar, the variable $P_{t-1}$ was included in the REH acreage model and the full system was reestimated. The rationale for inclusion of $P_{t-1}$ was that the REH model was now nested within a model with an extrapolative component. The likelihood ratio test of the restricted rational expectations model versus the more general expectations model yielded a calculated chi-square value of .0134 with one degree of freedom. The critical value for rejecting the rational expectations model at the .05 level would require a chi-square value greater than 3.84.

The REH and the cobweb model parameter estimates, however, show many close similarities. The results for the acreage equation appear reasonable in terms of the coefficients' signs and magnitudes. The rational expectations variable $P_{t-1}$ enters the equation quite significantly and with a magnitude twice that of the naive expectation. As expected, the opportunity costs associated with the rate of interest and the expected production costs have a negative effect on the acreage planted.

The yield equation illustrates the sensitivity of supply to current prices and labor costs. While the price elasticity of yield may appear unduly large, recall that this is essentially a structural supply equation. Thus, a sharp increase in yields acts to depress price through the resulting increase in supply.7/

The demand equation shows an own price elasticity of about -.8 for Florida tomatoes which appears reasonable in terms of other studies
(Nuckton). The effect of Mexican imports on the demand for Florida tomatoes is extremely significant and the \(-.8\) parameter suggests they are very close substitutes. The high income elasticity of demand is not surprising given that fresh winter tomatoes may be considered somewhat of a luxury item.

**Model Implications**

The structural models were solved for their reduced forms so that each endogenous variable could be expressed as a function of only the predetermined variables. The calculated reduced form parameters are presented in Table 2 along with their associated validation measures. Again, recall that all coefficients may also be interpreted as elasticities.

As discussed above, the REH variable, $P^*_t$, may be expressed as a linear combination of all predetermined and forecasted exogenous variables (except $W_t$). Since $P^*_t$ is consistent with the reduced form forecast of $P_t$ from the original model, their reduced forms should be related. This relationship is immediate if we assume that each forecasted exogenous variable is an unbiased estimate. Then, for example, we see that the coefficient on $M^*_t$ in the expectations equation equals the sum of the coefficients on $M_t$ and $M^*_t$ in the price equation.

The reduced form results in Table 2 underscore the importance of imports on expected prices and quantities in the Florida tomato industry. With regard to Florida tomato prices and quantities sold, a 10 percent increase in observed imports reduced price by 2.68\% (1.66\%) and quantity by 5.91\% (6.53\%) under the REH (dynamic cobweb). In other
words, a 10 percent increase in Mexican tomato imports, *ceteris paribus*, has the effect of reducing total Florida tomato revenues by 8.59% (8.19%). This relationship highlights the competitive nature of the winter tomato market.

The reduced form thus suggests that the dominant effect of Mexican tomato imports is on the reduction of domestic supply, not domestic price. As Mexican imports increase, not only does this reduce domestic supply, but correctly anticipated increases in imports (or lagged imports under the cobweb model) reduce domestic acreage. This strongly suggests that Mexican imports have had a significant influence on the contraction of the Florida industry in terms of acres planted. Moreover, the reduced form equation for acreage is the one equation that reveals a difference in predictive ability between the REH and the cobweb models. The $R^2$ is somewhat over twice as high as for the REH and the mean absolute error is about one-third less with the REH model as compared to the cobweb. Thus, although the REH does not offer significant improvements in predicting price or quantity over the simpler cobweb, the predictive ability for acreage is greatly improved with the additional information brought to bear through the rational expectations interpretation.

The long run effects of Mexican imports on Florida tomato acreage are illustrated with a dynamic analysis of the reduced forms. (Table 3). The long run response of acreage to imports is nearly four times as great under the REH model as compared to the cobweb model (-.447 vs. -.123). The results thus suggest considerably more acreage adjustment to anticipated imports, for example, than would be reflected by the
simpler cobweb model. Moreover, the REH estimates suggest that 42 percent of the acreage adjustment due to changes in anticipated imports occurs in the current time period. By contrast the cobweb model cannot reflect any adjustment in the current period.

Conclusions

The primary focus of this paper is interpreting the effect of Mexican tomato imports on the highly structured and centralized Florida winter tomato market. The unique feature of the approach taken in this paper is the specification of a rational expectations framework on the producers' expected price in the acreage decision. Previous efforts at estimating acreage and supply equations have typically assumed ad hoc price expectation specifications in order to compensate for the production time lag in the acreage decision equation. The most common of these is the cobweb model. By contrast, the rational expectations specification allows for the possibility that producers utilize all information available to them at the time planting decisions are made. They subsequently adjust their plantings on the basis of this information and in accordance with its implications as reflected through the supply and demand model.

We find that the rational expectations specification is consistent with the data for the winter tomato market. Moreover, the results suggest superior performance in interpreting acreage decisions than for the more typical cobweb model. As might be anticipated, the differences in yield and price predictions are not greatly different in the two cases. The reason is simply that the essential difference in the two
approaches is in the specification of the acreage equation. There is very little difference between the two models in either the composition or the coefficients of the reduced form equations other than acreage.

The significance of the rational expectations statement is that producers can and do adjust not only to historic price information, but more importantly to current information not necessarily reflected in past prices. If anticipated imports are higher than previously, domestic producers adjust in part by reducing plantings. As trade restrictions on tomatoes are reevaluated with Mexico, it is significant to note that the results of this paper suggest that Florida producers quickly and correctly adjust to the anticipated level of Mexican imports. Moreover, the impact is primarily on quantities rather than prices, and furthermore, a significant part of the quantity impact is attributed to acreage rather than the complete impact being absorbed by economic abandonment and the ensuing waste of resources once the crop has been planted.
Table 1. Maximum Likelihood Estimates

<table>
<thead>
<tr>
<th>Equation</th>
<th>Parameters</th>
<th>Variable</th>
<th>REH Model</th>
<th>Cobweb Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage</td>
<td>$a_0$</td>
<td></td>
<td>1.312 (1.26)$^a$</td>
<td>2.116 (1.715)</td>
</tr>
<tr>
<td></td>
<td>$a_1$</td>
<td>$P_r^b$</td>
<td>.917 (.332)</td>
<td>.460 (.152)</td>
</tr>
<tr>
<td></td>
<td>$a_2$</td>
<td>$C_t$</td>
<td>-.731 (.251)</td>
<td>-.484 (.158)</td>
</tr>
<tr>
<td></td>
<td>$a_3$</td>
<td>$R_t$</td>
<td>-.472 (.146)</td>
<td>-.256 (.082)</td>
</tr>
<tr>
<td></td>
<td>$a_4$</td>
<td>$A_{t-1}$</td>
<td>.756 (.322)</td>
<td>.544 (.183)</td>
</tr>
<tr>
<td>Yield</td>
<td>$\beta_0$</td>
<td></td>
<td>.588 (.490)</td>
<td>-.050 (1.18)</td>
</tr>
<tr>
<td></td>
<td>$\beta_1$</td>
<td>$P_{t-1}/P_t$</td>
<td>2.208 (1.12)</td>
<td>3.939 (3.05)</td>
</tr>
<tr>
<td></td>
<td>$\beta_2$</td>
<td>$W_t$</td>
<td>.209 (.073)</td>
<td>.319 (.150)</td>
</tr>
<tr>
<td></td>
<td>$\beta_3$</td>
<td>$X_t$</td>
<td>.215 (.119)</td>
<td>-.0143 (.304)</td>
</tr>
<tr>
<td>Demand</td>
<td>$\gamma_0$</td>
<td></td>
<td>-6.04 (1.14)</td>
<td>-6.42 (1.43)</td>
</tr>
<tr>
<td></td>
<td>$\gamma_1$</td>
<td>$P_t/D_t$</td>
<td>-.786 (.203)</td>
<td>-.837 (.239)</td>
</tr>
<tr>
<td></td>
<td>$\gamma_2$</td>
<td>$M_t$</td>
<td>-.801 (.118)</td>
<td>-.792 (.132)</td>
</tr>
<tr>
<td></td>
<td>$\gamma_3$</td>
<td>$I_t$</td>
<td>2.087 (.204)</td>
<td>2.112 (.232)</td>
</tr>
</tbody>
</table>

Log-likelihood

95.3664
93.9708

$^a$Estimated asymptotic standard errors are in parentheses.

$^b$This is $P_{t-1}$ under the cobweb model.
Table 3. Impact, Interim and Long-run Acreage Elasticities

<table>
<thead>
<tr>
<th>Period</th>
<th>REH</th>
<th>Cobweb</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$\frac{\Delta A_t}{\Delta M_{t-\theta}}$</td>
<td>$\frac{\Delta A_t}{\Delta M_{t-1-\theta}}$</td>
</tr>
<tr>
<td></td>
<td>Impact</td>
<td>Interim</td>
</tr>
<tr>
<td>0</td>
<td>.188</td>
<td>.188</td>
</tr>
<tr>
<td>1</td>
<td>.109</td>
<td>.297</td>
</tr>
<tr>
<td>2</td>
<td>.063</td>
<td>.360</td>
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<tr>
<td>3</td>
<td>.036</td>
<td>.396</td>
</tr>
<tr>
<td>4</td>
<td>.021</td>
<td>.417</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>n</td>
<td>0</td>
<td>-447</td>
</tr>
</tbody>
</table>
1/ Nelson has mentioned that "'rational' has deteriorated in current usage to little more than a synonym for 'unbiased' or 'optimal extrapolative'," (p. 331). Our usage conforms with Muth's definition that rational expectations "are essentially the same as predictions of the relevant theory," (p. 316).

2/ Kennan has shown that when a decision-maker is faced with a quadratic loss function containing both a disequilibrium cost and an adjustment cost the partial adjustment model can serve as a description of optimal behavior.

3/ One can logically argue that the demand equation should be specified as the demand for domestic and imported tomatoes. However, this introduces additional severe non-linearities into the system as well as the requirement for data to explain the level of exports from Mexico. This is beyond the scope of this paper and is left for future work.

4/ The disturbance terms have been deleted here since they will disappear upon taking expectations.

5/ Data on P and A were from Florida Vegetable Summary, C was from Costs and Returns from Vegetable Crops in Florida, R, D, and I were from Department of Commerce, L was from Walker and Florida Farm
Labor, Q was from Annual Report of the Florida Tomato Committee, and
M was from Preview of Mexico’s Vegetable Production for Export.

6/ See, for example, Intriligator, p. 412.

7/ In fact, if the underlying harvesting production function is assumed
to be of the form

\[ Y = \alpha H^\beta \]

where \( H \) represents the labor input, the elasticities from the
estimated supply equation

\[ Y = p^{2.208} L^{-2.208} \]

imply that the elasticity of production for the labor input be \( \beta =
.688. \)
References


