The Economic Cost of Huanglongbing (Citrus Greening) to Florida's Orange Industry: Estimates of Producer and Consumer Surplus

Charles B. Moss, Kelly Grogan, Derek Farnsworth, and Ariena VanBruggen

Introduction

This study estimates the economic impact of Hunglongbing (HLB) often referred to as Citrus Greening on Florida's orange industry using the economic welfare approach (Just, Hueth, and Schmitz 2004). Citrus green was initially observe in backyard citrus in South Florida in 2005 (Burrow et al. 2014). By February 2009 the disease had spread to every major citrus producing county in the state of Florida. Hodges and Spreen (2012) estimate that greening cost Florida $8.92 billion in revenue and $4.62 billion in gross domestic product between the 2006/2007 and 2010/2011 crop seasons. These estimates are generated using a mathematical programming model of Florida's citrus industry developed by Spreen, Brewster, and Brown (2003) that primarily focuses on the price levels for different types of citrus given different sources of demand. The economic impact on gross domestic product is then generated using IMPLAN (Mig, Inc. 2010). This study takes an the alternative approach of estimating the change in producer and consumer surplus based on a structural model of the supply and demand of Florida orange.

The Disease Vector

The spread of HLB is a multifaceted process. The damage to the tree is associated with the bacterium *Candidatus* Liberibacter asiaticus which attacks the tree's phloem. This has two effects: First, the outer branches accumulate sucrose either killing or significantly affecting fruit production. Second, the blockages in the phloem starves the roots, increasing the mortality rate for trees. The bacterium moves inside infected Asian citrus psyllids (*Diaphorina citri*). Infection of the citrus grove in Florida was a two-step process. In 1998, the Asian citrus psyllid was observed in Florida (Burrow et al. 2014). While the original source of the psyllid is unknown, one hypothesis is that the psyllids were imported with a shipment of orange jasmine (an ornamental shrub).[1] The exact mechanism for the introduction of the bacterium is unknown, but greening was first detected in residential areas.

Modeling HLB using Supply and Demand

Modeling the supply of a perennial crop such as oranges raises a complication not present in the estimation of supply for annual crops. Specifically, the supply of citrus is bounded by the number and age structure of trees at any point in time. French and Bressler (1962) explicitly recognize the role of the tree stock in their analysis of the lemon cycle. They start by hypothesizing that the number of lemon trees varies over time as producers plant new trees and remove older citrus. To model planting behavior, French and Bressler estimate the new plantings as a percentage of the bearing acreage as a function of the expected profit. They then use the average profit per acre over the last five crop years as expected profit. Given weak results for their tree removal equation, they use an autogressive model of lemon acres with a fifth-order lag term for expected profits to model the number of lemon trees. Multiplying this estimate time a fixed lemon yield per acre provides an estimate of the supply of lemons.

French and Matthews (1971) extend French and Bressler's model in two ways. First, they offer a more complicated planting model for asparagus. However, they also recognize the yield

[1] The source of citrus diseases is of significant interest in Florida. While the state has periodically experienced outbreaks of which is associated with the bacterium *Xanthomonas* axionopodis, the most recent outbreak which began in 1995 has been linked to the importation of citrus for backyard citrus. Whether backyard citrus was the entry point or not, significant conflicts emerged between urban homeowners and commercial growers during the canker eradication program.

mechanics inherent in a perennial crop. Specifically, older cohorts typically yield more than more recent plantings. In the case of oranges, the yield of a tree is proportional to its bearing volume where its bearing volume is determined by management and age. Wickens and Greenfield (1973) offer a slightly more general formulation of the yield curve for coffee production.

While the analogy is imperfect, these earlier efforts can be classified as hybrid primal production functions. The amount of output is modeled as a function of input usage (i.e., the number of trees in each cohort). Multiplying the yield per tree (possibly modeled as a function of other input decisions) times the number of trees yields the supply of the perennial crop. This study takes a slightly different approach. Specifically, we assume that producers maximize profits based on output and input prices, and the level of a quasi-fixed input (e.g., number of orange trees) similar to the approach taken by Morrison (1988). However, given our aggregate focus and the fact that we do not have a measure of profit, we implicitly apply Hotelling's lemma and directly estimate the supply of orange as a function of the orange price, the number of trees (our quasi-fixed variable), and the fuel price.

Using this formulation of the supply of orange as a function of the number of trees, we specify the supply and demand of citrus in as a two equation system

$$\begin{aligned} Q_D &= \alpha_0 \exp\left(\alpha_1 p + \alpha_2 e\right) + \varepsilon_1 \\ Q_S &= \beta_0 \exp\left(\beta_1 p + \beta_2 T + \beta_3 w\right) + \varepsilon_2 \end{aligned} \quad (1)$$

where Q_D is the quantity of orange demanded (in millions of field boxes), Q_S is the quantity of orange supplied, p is the price of citrus (in 2014 dollars per field box, e is the consumer expenditure on food (in 2014 dollars per household), T is the number of orange trees (in millions), w is the price index for fuel, and ε_1 and ε_2 are residuals. Equating the quantity supplied and demanded, we estimate the relationships in Equation 1 using nonlinear generalized method of moments. Specifically, letting

$$g_t\left(\varepsilon_t \middle| \alpha, \beta, Q_t, p_t, e_t, T_t, w_t\right) = \begin{bmatrix} Q_t - \alpha_0 \exp\left(\alpha_1 p_t + \alpha_2 e_t\right) \\ Q_t - \beta_0 \exp\left(\beta_1 p_t + \beta_2 T_t + \beta_3 w_t\right) \end{bmatrix} \tag{2}$$

the generalized method of moment objective function becomes

$$Q_t\left(\alpha, \beta\right) = \sum_{t=1}^{24} g_t\left(\varepsilon_t \middle| \alpha, \beta, Q_t, p_t, e_t, T_t, w_t\right)\left(z_t \otimes I_2\right)' W_T\left(z_t \otimes I_2\right) g_t\left(\varepsilon_t \middle| \alpha, \beta, Q_t, p_t, e_t, T_t, w_t\right)' \tag{3}$$

where z_t is a vector of instrumental variables and W_T is a weighting matrix (akin to the weighted covariance matrix for the instrumental variables). In our analysis, we use exogenous variables in our model household expenditures on food (e_t), the number of trees (T_t), and the price of fuel (w_t) as well as the price of agricultural chemicals and the agricultural wage rate. The relative small sample size (e.g., 24 years) limited our ability to include these other input prices directly in our supply curve, but we use their information for identification purposes as a part of the generalized method of moment estimation. The W_T matrix is constructed iteratively, initially we use a simple identity matrix. Given the first set of parameter estimates, we then derive

$$W_T = \left[z'z \otimes \hat{\Sigma}\left(\alpha, \beta\right)\right]^{-1} \tag{4}$$

where $\hat{\Sigma}\left(\alpha, \beta\right)$ is the estimated covariance matrix implied by Equation 2.

The parameter estimates for this specification are presented in Table 1. Given the relative small sample size, we estimated the standard errors for the parameters by bootstrapping. In general, the coefficients are consistent with our expectations. The demand for citrus at the farm level is fairly price inelastic. In addition, the consumption of oranges increases as the consumer's food expenditures increase. Similarly, the supply of citrus is fairly price inelastic. Consistent with our expectations, the supply increases as the number of orange trees increases and declines with an increase in the price of fuel. Solving the supply and demand relationships at the sample mean, we let consumer expenditures be 5.415 (thousand dollars per household), the number of bearing trees equal 65.86 (million bearing orange trees), and the price index for fuel becomes 1.6029. This results in 170.489 million boxes of citrus produced and consumed at a price of $ 7.6729 per field box. These figures are somewhat above the observed sample average of 177.983 million field boxed and $7.4974 per field box, but will within reason.

To examine the effect of greening on the orange market we start by reducing the number of trees to 57.145 million trees (e.g., the number of trees in the 2012-2013 season). This results in a 6.8 percent decline in the amount of citrus produced and consumed and an increase in the price of citrus of 12.0 percent (e.g., the new price of orange is $ 8.5935 per field box and 158.882 million field boxes are produced). This scenario depicts the case where greening simply reduces the number of bearing trees. An alternative scenario is that greening reduces the number of bearing trees and increases the cost of production. In this scenario we assume that the elasticity of supply increases by 1 percent. Taken together, these change result in a reduction in the quantity of citrus produced to 101.744 million boxes and a price of $ 14.4126 per field box. Table 2 presents the change in consumer and producer surplus from each of these scenarios.

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Table 1. General Method of Moments Results

Parameter	Estimate
Demand Constant (α_0)	14.9351
	(14.9636)[a]
Effect of Price on Demand (α_1)	-0.0766
	(0.1234)
Effect of Consumer Expenditure on Food on Demand (α_2)	0.5582***
	(0.2379)
Supply Constant (β_0)	0.6257***
	(0.1716)
Effect of Price on Supply (β_1)	0.4404***
	(0.0441)
Effect of Number of Trees on Supply (β_2)	0.0515***
	(0.0032)
Effect of Fuel Prices on Supply (β_3)	-0.8536***
	(0.1530)

[a]Numbers in parenthesis denote standard errors. ***Denotes statistical significance at the 0.01 level of confidence.

Table 2. Estimated Change in Consumer and Producer Surplus from Greening (Millions of Dollars per Year)

	Change in Tree Stock	Change in Tree Stock and Increased Supply Elasticity
Producer Surplus	-18.089	-141.976
Consumer Surplus	-154.927	-900.941
Total Welfare Effect	-173.015	1,042.920