ESSAYS ON THE ECONOMIC IMPACTS OF HUANGLONGBING ON FLORIDA'S CITRUS INDUSTRY

By

CARLOS RAUL PITTA ARCOS

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2019

ACKNOWLEDGMENTS

First and foremost, I want to thank my advisor and chair of the doctoral committee, Dr. Richard Weldon. He is one of the most generous, kind and patient people I know. All my gratitude for supporting and standing by me, even after all the anxiety and despair I sometimes felt, he always had kind words for me in spite of my many shortcomings. An endeavor like this couldn't be accomplished without the help of many people. I'd like to thank my doctoral committee: Dr. Derek Farnsworth for his encouraging words and expert advice; Dr. Ariel Singerman for his time and help; Dr. Hector Sandoval for his patience and guidance; Dr. Carlos Trejo for all the time, information and interest he showed for this work. All these people helped me even more than they know: the quality of their work, the technical expertise and clearness in exposing complex problems helped so much, sometimes without even the need to talk to them, the pure act of reading their work and knowing that I had the support of such expertise gave me the confidence and helped me so much during this period that I cannot thank them enough.

Many other people helped me during this PhD journey. Dr. Thomas Spreen and Dr. Richard Kilmer were formative figures for me during these many years. Dr. Robert Emerson who taught me more than econometrics. Dr. Ronald Muraro (†), whose work and devotion towards the citrus industry inspired me. I was lucky enough to interact directly, inside and outside the classroom, with incredible professors that not only taught me the discipline but helped me to mold the academician and person that I'm today: Dr. John VanSickle, Dr. Charles Moss, Dr. Ronald Ward, Dr. Robert Emerson, Dr. Andrew Schmitz, Dr. Charles Adams, among so many. Dr. Lisa House always supported me. I can never recall a time in which she didn't have a smile on her face. Jessica Herman

was always kind and helpful. So many other wonderful people in the department, old and new faculty, staff and students, all contributed to make this department so cozy, warm and heartfelt as a second home. Thanks to them for fostering a feeling of belonging to the University of Florida and letting me comprehend the true nature of the Gators Nation, a feeling that I will never forget.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

ESSAYS ON THE ECONOMIC IMPACTS OF HUANGLONGBING ON FLORIDA'S CITRUS INDUSTRY

By

Carlos Raul Pitta Arcos

July 2019

Chair: Richard Weldon
Major: Food and Resource Economics

The current dissertation studies the economics of Huanglongbing or HLB, an infectious citrus disease, and its effects on Florida's citrus industry's main commodities, orange and grapefruit. First we consider orange production, and we present a capital budgeting model that combines economic, financial and biological aspects of HLB to estimate the economic profitability of a stylized Floridian citrus grove, and contrasted three different management mechanisms to confront HLB: 1) Do nothing as a baseline scenario; 2) Undertake a foliar nutrition program to counteract the adverse effects of HLB; and 3) Implement a program of trunk injection of bactericides. The results suggest that new plantings of orange production in Florida is not profitable, as all three alternatives exhibit negative Net Present Values computed over a 15-year horizon. More mature orange groves can be profitable, depending on the strategy selected. In general, it has been found that a novel treatment consisting in the injection of plant activators and bactericides is, albeit costly, the most profitable management practice for all groves, regardless of average age and initial HLB incidence.

Secondly, we present a different methodology to analyze grapefruit production. We use a multi-market model that allocates grapefruit production into world markets in

order to calculate dynamic prices. We consider two scenarios in order to cope with HLB, doing nothing or implementing a trunk injection of bactericides. The results confirm that trunk injection is the best strategy in terms of production, but we also show that this increase in supply considerably affects forecasted prices in the long run. Grapefruit growers still face dire options: fighting HLB, which increases supply and reduces prices, or accepting as permanent historically low production levels.

CHAPTER 5
THE GRAPEFRUIT SUB-SECTOR

Importance of Grapefruit within Florida's Citrus Industry

In this chapter, we continue our effort to assess the economic impact of HLB in Florida's citrus industry by considering the disease's impact in grapefruit production. Grapefruit production in Florida used to be a major piece of the industry, but as the sector coped with HLB and other major natural disasters it has faced dismal prospects in the latest production seasons. In order to assess the economic impact of HLB in the grapefruit sector we present a model of the world market in which Florida's grapefruit is still a relevant player. Conceptually, the market is modeled using a linear multi market allocation methodology that is developed in two phases:

1) The first phase calculates a total supply quantity. This first phase can be subdivided into two scenarios: a) A normal scenario that follows strategy 1 of Chapter 3 of doing nothing, which constitute a baseline comparison scenario; and b) A second scenario is evaluated assuming that the producer follows strategy 3 of Chapter 3 which consist on applying an HLB management program of trunk injection of bactericides. Both scenarios take as inputs many findings of Chapter 3 such as all the logistic results in terms of spread and survival rates, which in turn affects yield and total production, which in turns allows to calculate total supply. The implicit assumption is that the biological results found in chapters 2 and 3 for orange production are also applicable to grapefruit production.

2) The second step calculates a world demand. In this phase, we allocate the total supply calculated in phase 01 into the most important world markets for fresh and processed fruit and for grapefruit varieties red and white, using several assumptions on

market size and demand elasticities. Finally, our model makes supply and demand interact in order to compute a dynamic forecast of production, allocation and on tree prices eleven years forward. This chapter contributes to the literature by using an otherwise common spatial equilibrium model, and then modify several assumptions and incorporate some epidemiological results from chapter 03 to be able to measure the impact of HLB on forecasted estimation of supply and prices, as well as to contrast those estimations with the effects of using a simulated response to cope with HLB.

The grapefruit sub-sector has always been a crucial part of Florida's citrus industry. At its zenith during the 2002-03 season, Florida's grapefruit production was an enormous player at international level, as it used to account for almost 80 percent of U.S. grapefruit production and more than half of the total world grapefruit production (USDA-NASS, 2017). It used to be the second largest commodity in the citrus sub-sector, representing about a fifth of the industry in terms of cash receipts from farming. Nowadays it is the third largest commodity after oranges and lemons, partly because as lemons and limes have shown more tolerance towards HLB infection growers have sometimes replaced orange and grapefruit production for lemon. However, as we are interested about the impacts produced by HLB in the citrus industry, we consider an analysis of the grapefruit sub-sector critical, particularly as Florida's grapefruit production remains a key international player next to China and South Africa (USDA-FAS, 2019).

After a combination of natural disasters in conjunction with the appearance of HLB occurred, the sector took a hit arguably even harder than orange production. Table 5-1 presents key indicators of Florida's grapefruit production. We can see how cash receipts, for instance, dropped from a peak of 290 million to 110, while the total number of acres went from 146 to 30 thousand. Production went down from a maximum of almost 56 million boxes during the 1996-97 season to 7.7 million during 2016-17, the last season for which we have available information. The total value of grapefruit production collapsed from a maximum of about 280 million to 87.

Multi-market Equilibrium Model

Supply

The supply side of our multi-market model is relatively simple: a perfectly inelastic supply with no transportation costs. However, in order to accurately calculate total production, the model first considers estimations using data on the number of grapefruit trees and yield of different age groups. The number of trees multiplied by the yield of each age group gives the production for that group. Thus, the production of each age group will be summed up to get the supply of grapefruit. Then, the total supply will be distributed to fresh and processed markets, both domestic and foreign. The production of seedy grapefruit, being almost negligible, has been ignored in the model.

This simple calculation is further complicated since we must take into consideration the economic impact of HLB. We build up from Chapter 3 by using the logistic estimates found there as parametric information to be used in order to calculate the probability of tree survival under two scenarios: a) Scenario 01, the baseline, considers the strategy do nothing; b) Scenario 02, the treatment effect, considers the strategy of employing trunk injection of bactericides in the same fashion as in Chapter 3. Table 5-2 presents the assumed effects of each scenario. This calculation is key as it is used as a proxy of tree mortality, which impacts the total number of trees for any given season, which in turns affects production, yield and finally grapefruit supply.

Yield and pack-out rates are initially considered from survey data (USDA-NASS, 2018) for production season 2016-2017, which becomes our baseline season. Then, the model uses this baseline information, as well as the impacts of HLB in terms of spread rate in order to estimate tree mortality, which effectively affects yield, production and costs for the seasons 2017-18 until 2027-28, which is our forecasted period.

The model defines two commodities, white grapefruit and red grapefruit, which are produced in two regions, the Indian river (IR) region and the interior (INT) region. The output is distributed to fresh and processed markets, both domestic and export, using two different HLB management strategies as previously described to calculate a total supply quantity that will assess HLB economic impacts once the demand of the most important markets is considered. This model is similar to the Takayama (1971) spatial equilibrium model except transportation costs are not included.

Demand

We consider two varieties, white and red grapefruit, and two utilizations, fresh and processed. In all, we have five markets: (1) domestic market for fresh white, (2) domestic market for fresh red, (3) export market for fresh white, (4) export market for fresh red and (5) the market for processed juice, following a modified approach by Pana-Cryan (1991). In our approach, no distinction is made between juice from white grapefruit and juice from red grapefruit. Red seedless and white seedless grapefruit are sold in both the domestic and export markets. We consider as export markets: (1)

Japan, (2) Canada, and (3) The European Union. Let the inverse derived demand in each fresh market at the output door of the packinghouse be:

$$P_{vj} = \alpha_{vj} - \beta_{vj} Q_{vj}^{D} \tag{5-1}$$

where P_{vj} is the price per box (one and three fifth bushels) of variety *v* (red and white) and market *j* (domestic and export); α_{vj} and β_{vj} are positive parameters and Q_{vj}^{D} is the quantity (i.e., number of boxes) of variety *v* and market *j*.

Now, assume the supply X_{vj} be the boxes of variety *v* sold in market *j*. The derived demand for the fresh markets is:

$$Q_{vj}^{D} = \lambda_{vj} X_{vj} \tag{5-2}$$

where X_{vj} differs from Q_{vj}^{D} because only a portion of the fruit intended for market *j* will meet the quality standard associated with market *j*. In the industry, the proportion of fruit that meets the fresh market standard is called the pack-out rate, denoted in Equation (5-2) by λ_{vj}. The portion of fruit that does not meet the specification of the fresh market is called eliminated fruit or "eliminations." Eliminations are sent to the processing plant to be processed into juice. Let the eliminated fruit be denoted by Q_{vj}^{E} and:

$$Q_{vj}^{E} = \left(1 - \lambda_{vj}\right) X_{vj} \tag{5-3}$$

Since differences in eliminated fruit are mainly cosmetic and does not affect the size of the fruit, it is safe to assume that the juice content of eliminated fruit is the same regardless of whether it was intended for the domestic or export market. Let *JU* be the juice yield associated with one box of grapefruit. In this analysis no attempt is made to differentiate between the juice derived from red seedless and white seedless grapefruit. Therefore, juice production is given by:

$$JP = \sum_{v} JU \left(\sum_{j} \left(1 - \lambda_{vj}\right) X_{vj} \right) \tag{5-4}$$

where *JP* denotes the single strength equivalent (SSE) gallons of juice produced in a season and *JU* is gallons of juice per box (4.8 gallons) that does not vary by variety. The inverse derived demand Equation (FOB at packinghouse) for grapefruit juice is:

$$P_J = \alpha - \beta Q_J \tag{5-5}$$

where P_J is the price per SSE gallon for market *j* and Q_J denotes the gallons consumed in market *j*. If juice inventory adjustment is ignored, then in any season:

$$JP = Q_J \tag{5-6}$$

Define PD_v as the total boxes of variety *v* in a season. Let PC_j be the packing costs per box associated with fruit destined for market *j*. The absence of a subscript for variety implies that packing costs do not depend upon variety. Let *PR* denote processing costs expressed in dollars per SSE gallon of final product.

With these assumptions and definitions, an allocation model can be written in which the competitive allocation of fruit by variety is:

$$\begin{aligned} \text{Max} \ & \sum_{v} \sum_{j} \int \left(\alpha_{vj} - \beta_{vj} Q_{vj}^{D} \right) dQ_{vj}^{D} + \int \left(\alpha - \beta Q_J \right) dQ_J - \sum_{v} \sum_{j} PC_j Q_{vj}^{D} - PR\, Q_J \\ s.t. \quad & a) \quad \sum_{j} X_{vj} + FR_v \le PD_v \qquad v = \text{red, white} \\ & b) \quad Q_{vj}^{D} \le \lambda_{vj} X_{vj} \qquad j = \text{domestic, export} \\ & c) \quad Q_J \le \left(\sum_{v} JU \left(\left(\sum_{j} \left(1 - \lambda_{vj}\right) X_{vj} \right) + FR_v \right) \right) \end{aligned} \tag{5-7}$$

where FR_v is the quantity of variety *v* that goes from the grove directly to the processing plant. All variables are non-negative.

In essence, this is a multi-market equilibrium model with the slight variation from other specifications in the literature (Pana-Cryan, 1991) that supply is determined each season. Also, no transportation costs are considered. The output markets are FOB at packinghouse. The objective function (Equation 5-7) maximizes the area under the derived demand functions at the equilibrium quantities for all the markets. It allocates fruit to fresh and processed markets to attain equilibrium prices given that the supply of grapefruit is fixed in the short run, which implies supply is perfectly inelastic, as the producers cannot respond to a price change in the short run. It takes at least three years after producers plant new trees for them to bear fruit. The first constraint (set of Equations 5-7a) in the model balances total derived demand with supply, which ensures that boxes sent to the packinghouse for fresh domestic and export markets along with the boxes sent directly to the processing plant (field run) for the juice market must be less than or equal to the total production of each type of grapefruit. The second constraint (set of Equations 5-7b) is the balancing constraint between boxes sent to the packinghouse and the boxes packed for fresh use. The last constraint (set of Equations 5-7c) represents the balance between juice from the boxes not qualified for the fresh market (elimination) plus juice from the field run boxes with total consumption of juice. Juice storage is not allowed in this specification.

The algorithm uses historical data from season 1992-93 up until season 2016-17, then uses the information to calculate optimal values for each year. Season 2017-18 is the first season forecasted by the model. At that point, prices and quantities of equilibrium are found FOB at packinghouse. Then, the model performs the same subroutine for each one of the following years until the 2027-28 season, iterating from the previous year's optimal values and updating a solution for each year. One derived supply point and five derived demand points (two domestic and two export for fresh red and white, and one for juice) are specifically described in this model. Since juice exports are minimal, the two juice demand points (domestic and export) are assumed to be one.

Data and Assumptions

The yield data for grapefruit trees by age groups were collected from various issues of the Citrus Summary (USDA-NASS, 2018). Citrus summaries present data in cohorts according to the age of trees, clustered in cohorts from 3 to 5 years, 6 to 8 years, 9 to 13 years, 14 to 23 years, and finally 24 years and above. Since the data are for a range of tree ages. In order to get a point estimation for each number of years of age, the data from citrus summaries was interpolated. The tree inventory numbers are also taken from FASS publication (Commercial Citrus Inventory, 2002). The problem of unidentified trees (of less than 3 years old) allocated into white or red grapefruit has been minimized by using the percentage of their respective identified numbers.

Another determinant of supply is new tree planting dynamics. We specify one equation for plantings of new grapefruit trees as:

$$NEWPLANT_{v,t} = \alpha_{0v} + \alpha_{1v} \cdot PLANT_{v,t-1} + \mu_t \qquad (5\text{-}8)$$

where, $NEWPLANT_{v,t}$ is the new planting of grapefruit trees of variety v in period t, $PLANT_{v,t-1}$ is grapefruit trees of variety v planted in period t-1 and μ_t is a stochastic error term. Parameter estimation of Equation 5-8 has found the intercept to be statistically non significant and values for α_{0red} and α_{1red} of -39.7 and 0.58 respectively for red grapefruit, and of α_{0white} = -110 and of α_{1white} = 0.57 for white variety (Ali, et al., 2000).

In order to calculate demand equations, elasticity estimation from previous studies (Brown and Lee, 2002, Perez and Pollack, 2003), as well as current FOB packinghouse prices were used assuming a linear demand. The equations for red and white fresh grapefruit exports to Canada are estimated based on an own price elasticity of - 1.67 (Lee, 2004). The same strategy was employed in order to calculate demand functions for fresh grapefruit exported to Europe and Japan (Lee, 2004), as well grapefruit juice demand. The pack-out rates are based on an informal survey (Muraro, et al., 2003); however, the pack-out rates used in the model were slightly adjusted in order to calibrate the FOB prices and quantities.

The model also employs several other parameters such as processing costs of grapefruit and packing costs for sending the produce which varies depending on the market, which are difficult to estimate. We used previous estimations of these parameters from several sources (Muraro, 2004, Muraro, 2010, Muraro, et al., 2003). However, since some estimations have not been updated, we adjusted them using CPI values as previously suggested by Trejo-Pech, et al. (2018). Other values such as grapefruit juice single strength gallons yield and price for the base season of 2016-17 were taken directly from statistical sources (USDA-NASS, 2018).

Empirical Results for Red Grapefruit

Model estimation for key variables forecasted by the model is presented in Tables 5-3 and 5-4, which shows estimations for scenario 01 and 02 respectively. The model uses historical information, as well as data from the 2016-17 season, to compute a solution for the baseline for the first year, allocates production and forecast prices, new plantings and total trees for season 2017-18, and then repeats the process iteratively until the end of the forecasted period, season 2027-28. As expected, total production declines rapidly under the doing nothing assumption, or scenario 01, and remains relatively stable up until the end of the forecasted period. In accordance with the relative scarcity of production, price increases from $15.70 which is the actual figure achieved in season 2017-17, to around $20 in average, reaching a peak of $22.59 in season 2021-22. After that the price tends to stabilize below $20 per box.

Column (b) reports total utilization, and is almost identical to total production, meaning than the model allocates total production between fresh consumption and processed fruit almost frictionless, with wastes being almost nil. The model also computes new plantings (column d) considering a rule of tree replacements of three trees per acre as it was assumed in Chapter 3, and estimates the number of total trees (column e) which responds very slowly at the beginning of the period, until the yearly change is composed and increases importantly by the end of the forecasted period.

The difference in terms of total production is very significant when we consider the different scenarios proposed. Total production under the assumption of doing nothing is significantly lower for every year when compared with the scenario in which trunk injections are used. Commensurate with less supply, on tree prices remain higher on average for scenario 01. The behavior of these key variables is summarized graphically in Figure 5-1.

Empirical Results for White Grapefruit

The estimation for white grapefruit, presented in Tables 5-5 and 5-6 and summarized in Figure 5-2, portray a dire situation for the commodity. The production figure of 1,480,000 boxes achieved during the 2016-17 is the lowest production point ever for Florida white grapefruit, and as the model uses it as a baseline for calculation it shows a production forecast that never fully recovers under the do nothing scenario. Total production under scenario 01 stays almost flat for the forecasted season of 2017-18, and then falls consistently and increases only partially to finish at 1,078,000 boxes at the end of the forecast horizon on 2017-28. Accordingly, on-tree prices remain relatively high, reaching a maximum value of $21.61 per box on season 2022-23 and then decreases as a reduction in supply is not capable of counteracting a weak demand.

Following a strategy of administering Trunk injection of bactericides achieves its goal of recovering total production, which increases every year of the forecast period, more than doubling the baseline production figure to 3,002,000 boxes on season 2027-28. However, this has a negative effect on prices as they remain relatively flat by the beginning of the forecast period until eventually leveling down to around $10 per box at the end, a decrease of almost 50%. The total number of trees jumps from 808,000 in 2016-17 to 1,539,000 in 2027-28.

Simulation 1, Changes in Planting Equation

Suppose that we want to make more explicit the role of output prices in the decision-making process of growers. One way to do this is to modify Equation 5-8 to incorporate lag price dynamics (Kalaitzandonakes, 1992) as in:

$$NEWPLANT_{v,t} = \alpha_{0v} + \alpha_{1v} \cdot PLANT_{v,t-1} + \alpha_{2v} \cdot MOVAVG_{v} + \gamma_{t} \qquad (5\text{-}9)$$

In which MOVAVGv is a three-year moving average of the on-tree price of grapefruit variety *v* and γ_t a stochastic error term. Empirical estimation of Equation 5-9 have found intercept to be statistically non significant while both parameters for PLANT and MOVAVG are statistically significant and close to one (Spreen, et al., 2007).

Simulation results are presented in Tables 5-7 and 5-8 for red variety, and 5-9 and 5-10 for white grapefruit. A graphic summary of key forecasted variables is also presented in Figures 5-3 and 5-4 for red and white varieties respectively. Table 5-7 presents the results under strategy 1, doing nothing, and it calculates total production, utilization, on-tree prices, new plantings and total trees. Under strategy 1 total production falls deeply until season 2021-22 and then start to recover, albeit slowly. Correspondingly, on-tree prices jump to a high of $22.78 in the same season, and then start to decrease. Table 5-8 shows how employing a program of trunk injection of bactericides increases production consistently and under all the forecasted period, which decreases prices every year until a minimum of $12.55 is reached at season 2027-28.

Results of strategy 1 for white variety are shown in Table 5-9. We can see a small increase in production right after the first year probably due to previous tree stock inertia, but then decreases deeply to a minimum of 486 thousand boxes in season 2023-24, less than a third of the 1,480 boxes produced during season 2016-17. On-tree price increases to a maximum of $23.32 in the same season, and only after those high prices are realized production starts to increase, although it never recovers completely, ending the forecasted season with a production of 786 thousand boxes and an on-tree price of $18.13.

Table 5-10 presents the results of assuming that a program of trunk injections is used for white grapefruit portraying a completely different situation. The modeled yield impact of the program consistently increases production every season until reaching a maximum of 2,660 thousand boxes at the end of the forecast in season 2027-28. Conversely, prices decrease in all the years reaching the lowest value of $12.21 in the same year. Those on-tree prices are very low, and a calculation done using the results on Table 5-10 show that total revenue can be as low as 11.3 million dollars for season 2023-24. As is not clear that such low revenue level can support the increasing costs of programs to cope with HLB, further research is necessitated.

Finally, as chapter summary, we used a multi-market model in order to calculate supply and demand for the grapefruit subsector of the citrus industry. We evaluated two scenarios to cope with HLB, doing nothing or implementing a trunk injection of bactericides. The results confirm that trunk injection is the best strategy in terms of production, but we also show that this increase in supply considerably affects forecasted prices in the long run, so growers still face dire options, fighting HLB and learning to live with the depressed prices forecasted by the model, or accepting as permanent historically low production levels if not.

Table 5-1. Key indicators of Florida's grapefruit citrus production compared before and after HLB occurrence.

Indicator	Before HLB Value (Year)	After HLB Value (Year)	Size, relative to max value
Cash receipts (x1000 $)	290,178 (2006-07)	110,990 (2016-17)	38%
Acreage (acres)	146,915 (1994-95)	30,923 (2017-18)	21%
Production (x1000 boxes)	55,800 (1996-97)	7,760 (2016-17)	14%
Price per Box ($)	13.47 (2004-05)*	11.30 (2016-17)	83%
Value of Production (x1000 $)	280,629 (1991-92)	87,574 (2016-17)	31%

* Atypical value as a result of Hurricane Charley. For comparison, average price in previous season (2003-04) was $3.33. The value in parenthesis below the figure represents the season in which such value was achieved.

Table 5-2. Modeled assumption on the effect of HLB on the probability of survival for two management strategies: Do Nothing and Trunk Injection of bactericides.

Tree Age	Variety	Ir	Inter	Ir	Inter
		Do Nothing		Trunk Injections	
1	Red	0.99	0.99	0.99	0.99
1	White	0.99	0.99	0.99	0.99
2	Red	0.99	0.99	0.99	0.99
2	White	0.99	0.99	0.99	0.99
3	Red	0.98	0.99	0.98	0.99
3	White	0.97	0.98	0.98	0.99
4	Red	0.96	0.96	0.98	0.98
4	White	0.92	0.92	0.98	0.98
5	Red	0.88	0.88	0.98	0.98
5	White	0.86	0.86	0.98	0.98
6	Red	0.82	0.82	0.98	0.98
6	White	0.82	0.82	0.98	0.98
7	Red	0.77	0.77	0.98	0.98
7	White	0.77	0.77	0.98	0.98
8	Red	0.76	0.76	0.98	0.98
8	White	0.75	0.75	0.98	0.98
9	Red	0.74	0.74	0.98	0.98
9	White	0.73	0.73	0.98	0.98
10	Red	0.72	0.73	0.97	0.98
10	White	0.68	0.69	0.97	0.98

Table 5-2. Continued

Tree Age	Variety	Ir	Inter	Ir	Inter
		Do Nothing		Trunk Injections	
11	Red	0.68	0.68	0.97	0.97
11	White	0.68	0.68	0.97	0.97
12	Red	0.68	0.68	0.97	0.97
12	White	0.68	0.68	0.97	0.97
13	Red	0.68	0.68	0.97	0.97
13	White	0.68	0.68	0.97	0.97
14	Red	0.68	0.68	0.97	0.97
14	White	0.68	0.68	0.97	0.97
15	Red	0.68	0.68	0.97	0.97
15	White	0.68	0.68	0.97	0.97
16	Red	0.67	0.68	0.96	0.97
16	White	0.67	0.68	0.96	0.97
17	Red	0.67	0.67	0.96	0.96
17	White	0.67	0.67	0.96	0.96
18	Red	0.67	0.67	0.96	0.96
18	White	0.67	0.67	0.96	0.96
19	Red	0.67	0.67	0.96	0.96
19	White	0.67	0.67	0.96	0.96
20	Red	0.67	0.67	0.96	0.96
20	White	0.67	0.67	0.96	0.96
21	Red	0.67	0.67	0.95	0.96
21	White	0.67	0.67	0.95	0.96
22	Red	0.67	0.67	0.95	0.96
22	White	0.67	0.67	0.95	0.96
23	Red	0.67	0.67	0.95	0.95
23	White	0.67	0.67	0.95	0.95
24	Red	0.66	0.67	0.94	0.95
24	White	0.66	0.67	0.94	0.95
25	Red	0.66	0.66	0.94	0.94
25	White	0.66	0.66	0.94	0.94

Survival rate probability under doing nothing consider regular pesticides and tree replacement but no additional effort to contain HLB spread rate. Trunk injection of bactericides is assumed to be as effective in containing HLB as the historical survival rates prior to HLB appearance.

Table 5-3. Baseline model forecast for key variables under the strategy Do Nothing, for Red Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	6,280	6,280	15.70	76	3,183
2017-18	5,193	5,193	19.26	222	1,827
2018-19	3,762	3,762	20.87	429	1,547
2019-20	2,772	2,772	22.00	637	1,621
2020-21	2,274	2,274	22.59	856	1,998
2021-22	2,329	2,329	22.59	1,081	2,652
2022-23	2,821	2,821	22.14	1,307	3,559
2023-24	3,662	3,662	21.33	1,528	4,685
2024-25	4,819	4,819	20.19	1,741	5,989
2025-26	6,237	6,237	18.77	1,943	7,425
2026-27	7,867	7,867	17.13	2,131	8,947
2027-28	9,656	9,656	15.32	2,303	10,516

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-4. Baseline model forecast for key variables under the strategy Trunk Injection of bactericides, for Red Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	6,280	6,280	15.70	76	3,183
2017-18	7,273	7,273	16.89	214	2,457
2018-19	7,270	7,270	16.85	400	2,577
2019-20	7,233	7,233	16.87	570	2,882
2020-21	7,350	7,350	16.73	739	3,353
2021-22	7,746	7,746	16.33	906	3,988
2022-23	8,381	8,381	15.69	1,070	4,780
2023-24	9,224	9,224	14.83	1,227	5,723
2024-25	10,331	10,331	13.72	1,375	6,808
2025-26	11,658	11,658	12.37	1,513	8,022
2026-27	13,243	13,243	10.87	1,637	9,353
2027-28	15,105	15,105	9.13	1,746	10,783

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-5. Baseline model forecast for key variables under the strategy Do Nothing, for White Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	1,480	1,480	18.50	27	808
2017-18	1,521	1,521	17.52	38	503
2018-19	1,136	1,136	18.77	55	409
2019-20	851	851	19.53	76	367
2020-21	672	672	19.81	99	372
2021-22	572	572	21.17	122	415
2022-23	546	546	21.61	146	490
2023-24	577	577	20.31	170	592
2024-25	654	654	18.13	193	715
2025-26	769	769	17.25	214	854
2026-27	912	912	16.17	234	1,005
2027-28	1,078	1,078	14.94	254	1,161

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-6. Baseline model forecast for key variables under the strategy Trunk Injection of bactericides, for White Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	1,480	1,480	18.50	27	808
2017-18	2,125	2,125	15.55	37	666
2018-19	2,187	2,187	15.49	52	681
2019-20	2,212	2,212	15.48	71	710
2020-21	2,248	2,248	15.36	89	757
2021-22	2,289	2,289	15.05	107	821
2022-23	2,347	2,347	14.57	125	903
2023-24	2,428	2,428	13.93	143	1,001
2024-25	2,532	2,532	13.09	160	1,115
2025-26	2,662	2,662	12.07	176	1,243
2026-27	2,818	2,818	10.86	191	1,385
2027-28	3,002	3,002	9.44	205	1,539

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-7. Simulation 1: forecast for key variables under the strategy Do Nothing, for Red Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	6,280	6,280	15.70	112	2,475
2017-18	5,193	5,193	19.26	185	1,863
2018-19	3,762	3,762	20.87	289	1,546
2019-20	2,812	2,812	21.96	394	1,480
2020-21	2,300	2,300	22.57	395	1,615
2021-22	2,145	2,145	22.78	508	1,810
2022-23	2,282	2,282	22.68	622	2,150
2023-24	2,522	2,522	22.46	737	2,611
2024-25	2,867	2,867	22.11	850	3,169
2025-26	3,439	3,439	21.53	961	3,804
2026-27	4,138	4,138	20.81	1,069	4,504
2027-28	4,937	4,937	19.99	1,174	5,257

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-8. Simulation 1: forecast for key variables under the strategy Trunk Injection of bactericides, for Red Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	6,280	6,280	15.70	112	2,475
2017-18	7,273	7,273	16.89	182	2,493
2018-19	7,270	7,270	16.85	275	2,580
2019-20	7,274	7,274	16.83	360	2,759
2020-21	7,381	7,381	16.71	445	3,022
2021-22	7,586	7,586	16.49	529	3,366
2022-23	7,916	7,916	16.16	613	3,788
2023-24	8,360	8,360	15.71	694	4,287
2024-25	8,959	8,959	15.10	774	4,859
2025-26	9,658	9,658	14.39	850	5,500
2026-27	10,490	10,490	13.55	923	6,206
2027-28	11,470	11,470	12.55	991	6,971

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-9. Simulation 1: forecast for key variables under the strategy Do Nothing, for White Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	1,480	1,480	15.70	25	661
2017-18	1,521	1,521	17.52	32	501
2018-19	1,136	1,136	18.77	42	402
2019-20	849	849	19.51	55	348
2020-21	663	663	19.79	67	332
2021-22	548	548	21.89	91	344
2022-23	494	494	23.24	104	389
2023-24	486	486	23.32	119	452
2024-25	523	523	22.14	133	531
2025-26	595	595	19.90	147	620
2026-27	681	681	18.61	160	717
2027-28	786	786	18.13	173	819

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

Table 5-10. Simulation 1: forecast for key variables under the strategy Trunk Injection of bactericides, for White Grapefruit.

Production Season	Total Production (a)	Total Utilization (b)	On tree price (c)	New plantings (d)	Total Trees (e)
2016-17*	1,480	1,480	15.70	25	661
2017-18	2,125	2,125	15.55	32	664
2018-19	2,187	2,187	15.49	41	674
2019-20	2,210	2,210	15.46	52	692
2020-21	2,240	2,240	15.35	63	720
2021-22	2,267	2,267	15.18	73	759
2022-23	2,300	2,300	14.93	84	807
2023-24	2,344	2,344	14.59	94	865
2024-25	2,402	2,402	14.14	104	932
2025-26	2,473	2,473	13.60	115	1,007
2026-27	2,559	2,559	12.97	124	1,091
2027-28	2,660	2,660	12.21	134	1,183

* Season 2016-17 data is the baseline, taken from Florida citrus statistics. (a) and (b) in thousands of boxes; (c) in dollars per box; (d) and (e) in thousands of trees.

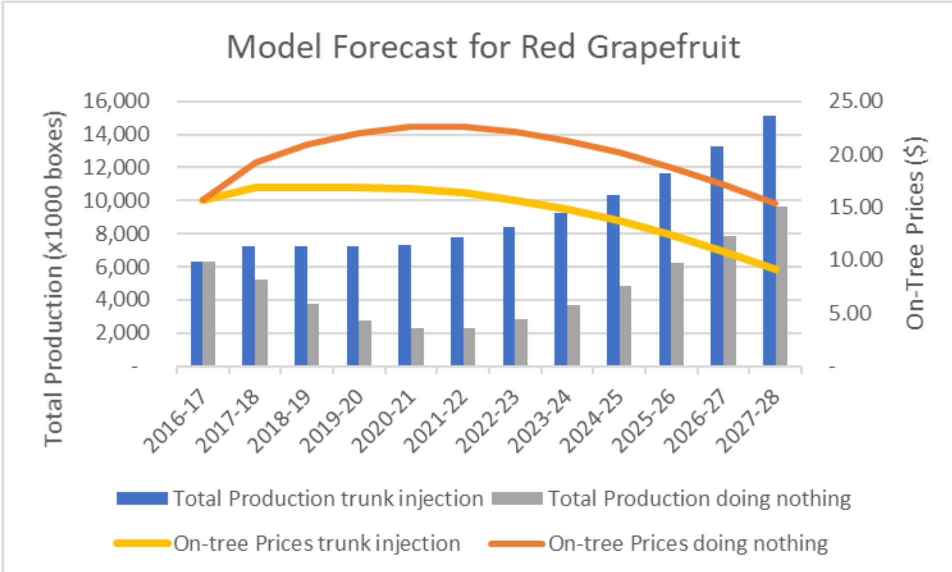

Figure 5-1. Multi market model forecast for Red Grapefruit of two key variables, total production and on-tree prices, for scenario 01 of doing nothing, and scenario 02 of applying Trunk Injection of bactericides.

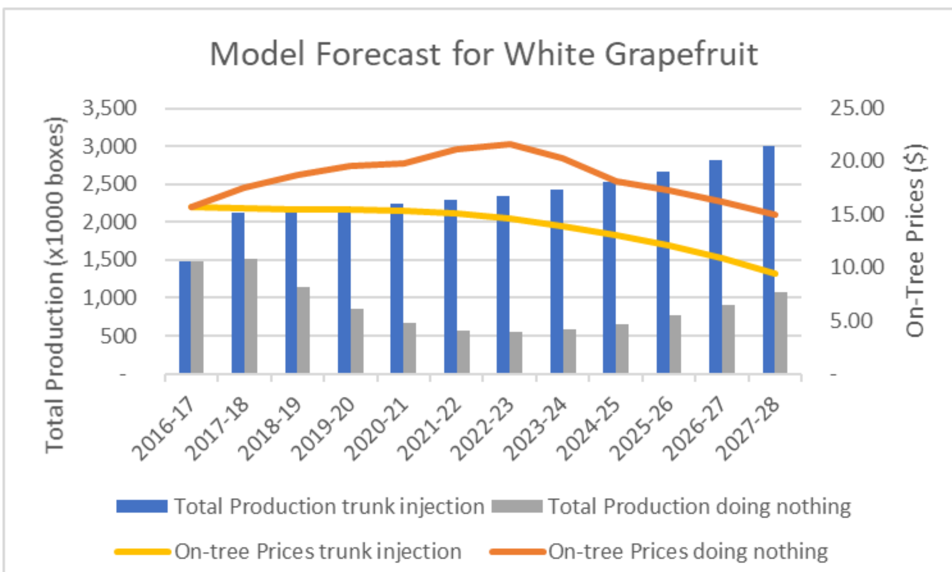

Figure 5-2. Multi market model forecast for White Grapefruit of two key variables, total production and on-tree prices, for scenario 01 of doing nothing, and scenario 02 of applying Trunk Injection of bactericides.

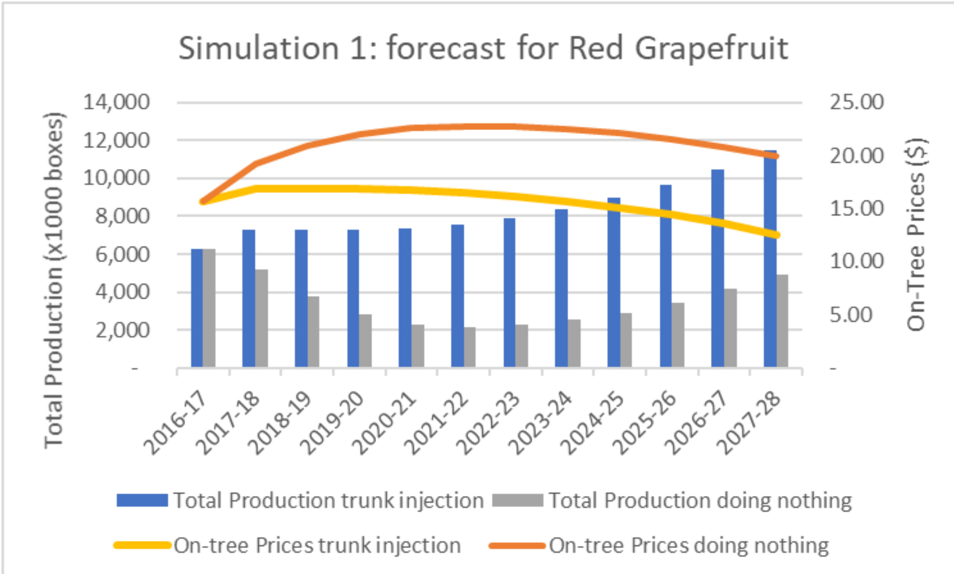

Figure 5-3. Simulation 1: multi market model forecast for Red Grapefruit of two key variables, total production and on-tree prices, for scenario 01 of doing nothing, and scenario 02 of applying Trunk Injection of bactericides.

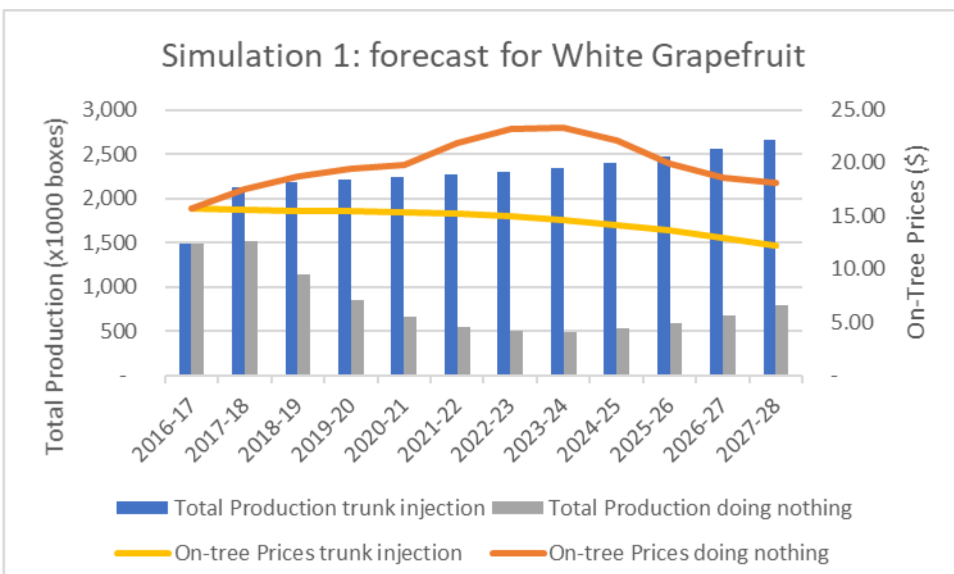

Figure 5-4. Simulation 1: multi market model forecast for Red Grapefruit of two key variables, total production and on-tree prices, for scenario 01 of doing nothing, and scenario 02 of applying Trunk Injection of bactericides.

CONCLUSIONS

Everywhere one goes in Florida one is reminded of the importance of the citrus industry: from the fruit stands on the edge of the road, to the colors at our university and the license plates of most of the vehicles. Citrus production is as Floridian as the alligators. In fact, the state of Florida used to be the third largest orange producer, only behind Brazil and China. This is not so anymore. The culprit is HLB, an infectious disease for which we do not have a confirmed and permanent cure.

One of the initial motivations to undertake this research was not only the utmost importance of the citrus industry for the state, but also the need to provide a rigorous answer to the dismal question that seemed to prevail in both industry and academic circles: Could it be that HLB may achieve what decades of weather events didn't? Could this be really the end of the citrus industry in Florida?

This dissertation has studied the economics of HLB and its effects on Florida's citrus industry. It first modeled the economic profitability of a stylized Floridian orange citrus grove, and contrasted three different management mechanisms to confront HLB: 1) Do nothing as a baseline scenario a control comparison; 2) Undertake a foliar nutrition program to counteract the adverse effects of HLB; 3) Implement a program of trunk injection of bactericides. The results suggest that, regardless of the management control strategy employed, any new commercial citrus operation is unprofitable, at least under the considered assumptions. This does not imply the end of the citrus industry, as more mature groves continue to be profitable.

Then, we focused on grapefruit production, which has been decimated in the last couple of years. We considered the effects of doing nothing or implementing a trunk injection program of bactericides to manage HLB. The results, which of course depend on many factors and uncertainties, are not particularly encouraging. Grapefruit growers face a dire choice of fighting HLB, which depresses prices as new treatments are starting to get more and more effective overtime or doing nothing and accepting both the smaller size of the industry and the higher prices that a reduced supply implies.

Overall, the results suggest that the industry must continue to wait for current efforts directed to achieve a real, long term solution for HLB, such as genuinely HLB resistant rootstock or a combination of new bactericides and plant activators that may prove to fully immunize citrus trees. We will continue to have orange juice on our breakfast table regardless. But we may end up paying a little more for it.

LIST OF REFERENCES

Albrecht, U., and K.D. Bowman. 2012. "Transcriptional response of susceptible and tolerant citrus to infection with Candidatus Liberibacter asiaticus." *Plant Science* 185:118-130.

Ali, M., R.L. Kilmer, T.H. Spreen, and C. Pitta. 2000. "An economic model for evaluating the impact of prohibiting the use of copper in grapefruit production of Florida." University of Florida.

Alvarez, S., D. Solis, and M. Thomas (2015) "Can Florida's citrus industry be saved while preserving the environment." In *An economic analysis for the bio-control of the Asian Citrus Psyllid. 2015 Annual Meeting.*

Ayres, A., C. Massari, S. Lopes, R. Bassanezi, J. Belasque, T. Yamamoto, D. Teixeira, N. Wulff, N. Gimenes-Fernandes, and O. Bergamaschi (2005) "Proceedings." In *International Citrus Canker and Huanglongbing Research Workshop.* Orlando.

Bassanezi, R., and R. Bassanezi (2008) "An approach to model the impact of Huanglongbing on citrus yield." In *Proceedings of the International Research Conference on Huanglongbing.* Orlando.

Bassanezi, R., A. Bergamin Filho, L. Amorim, and T. Gottwald (2006) "Epidemiology of huanglongbing in São Paulo." In *Proceedings of Huanglongbing Greening International Workshop, Ribeirão Preto.* pp. 37.

Bassanezi, R., A. Bergamin Filho, L. Amorim, and T. Gottwald (2006) "Epidemiology of Huanglongbing in São Paulo." In *Huanglongbing Greening International Workshop.* Ribeirão Preto.

Bassanezi, R., L. Busato, L. Amorim, and T. Gottwald (2005) "Preliminary spatial pattern analysis of Huanglongbing in São Paulo, Brazil." In *International Organization of Citrus Virologists Conference Proceedings (1957-2010).*

Bassanezi, R.B., L.H. Montesino, M.C.G. Gasparoto, A. Bergamin Filho, and L. Amorim. 2011. "Yield loss caused by huanglongbing in different sweet orange cultivars in São Paulo, Brazil." *European Journal of Plant Pathology* 130:577-586.

Bouffard, K. (2019) "Surge of OJ imports pushing down Florida citrus growers' prices." In. Bartow, Florida, The Ledger, pp. Florida citrus growers have seen the 2018-2019 season go from bad to dire.

Bové, J.M. 2006. "Huanglongbing: a destructive, newly-emerging, century-old disease of citrus." *Journal of plant pathology*:7-37.

Brlansky, R., K. Chung, and M. Rogers. 2012. "2006 Florida citrus pest management guide: Huanglongbing (citrus greening)." *UF/IFAS Extension*.

Brlansky, R.H., M.M. Dewdney, and M.E. Rogers. "Huanglongbing (Citrus Greening)." University of Florida.

Brown, M.G., and J.-Y. Lee. 2002. "Restrictions on the effects of preference variables in the Rotterdam model." *Journal of agricultural and applied economics* 34:17-26.

Carrascoa, L.R., A. Macleodb, J.D. Knighta, R. Bakerb, and J.D. Mumforda. 2009. "Optimal Control of Spreading Biological Invasions: For How Long Should We Apply the Brake?".

Chiyaka, C., B.H. Singer, S.E. Halbert, J.G. Morris, and A.H. van Bruggen. 2012. "Modeling huanglongbing transmission within a citrus tree." *Proceedings of the National Academy of Sciences* 109:12213-12218.

Council, N.R. 2010. *Strategic planning for the Florida citrus industry: addressing citrus greening disease*: National Academies Press.

de Almeida, E.P., V. Janeiro, T.A. Guedes, F. Mulati, J.W. Pedroza Carneiro, and W.M. de Carvalho Nunes. 2016. "Modeling citrus huanglongbing data using a zero-inflated negative binomial distribution." *Acta Scientiarum-Agronomy* 38:299-306.

Farnsworth, D., K.A. Grogan, A.H. van Bruggen, and C.B. Moss. 2014. "The potential economic cost and response to greening in Florida citrus." *Choices* 29:1-6.

---. 2014. "The potential economic cost and response to greening in Florida Citrus." *Choices* 29.

Florida, U.o. (2016) "Injecting citrus tree trunks with bactericide may help stem greening." In phys.org ed. *Biology.*

Folimonova, S.Y., and D.S. Achor. 2010. "Early events of citrus greening (Huanglongbing) disease development at the ultrastructural level." *Phytopathology* 100:949-958.

Futch, S., S. Weingarten, and M. Irey (2009) "Determining HLB infection levels using multiple survey methods in Florida citrus." In *Proc. Fla. State Hort. Soc.* pp. 152-157.

Garcia-Ruiz, F., S. Sankaran, J.M. Maja, W.S. Lee, J. Rasmussen, and R. Ehsani. 2013. "Comparison of two aerial imaging platforms for identification of Huanglongbing-infected citrus trees." *Computers and Electronics in Agriculture* 91:106-115.

Gatineau, F., H. Loc, N. Tuyen, T. Tuan, N. Hien, and N. Truc (2006) "Effects of two insecticide practices on population dynamics of Diaphorina citri and huanglongbing incidence in south Vietnam." In *Proc. Huanglongbing Green. Int. Workshop.* Ribeirão Preto, Braz. Araraquara, Braz. Fundecitrus, pp. 110.

Gottwald, T., B. Aubert, and K.L. Huang (1991) "Spatial pattern analysis of citrus greening in Shantou, China." In *Proc. 11th Conference of the International Organization of Citrus Virologists. Riverside, CA.* pp. 421-427.

Gottwald, T., M. Irey, T. Gast, S. Parnell, E. Taylor, and M. Hilf (2010) "Spatio-temporal analysis of an HLB epidemic in Florida and implications for spread." In *Proc. 17th Conf. IOCV.* pp. 84-97.

Gottwald, T., M. Irey, T. Gast, S. Parnell, E. Taylor, and M. Hilf (2010) "Spatio-temporal analysis of an HLB epidemic in Florida and implications for spread." In *International Organization of Citrus Virologists Conference Proceedings (1957-2010).*

Gottwald, T.R., J.V. da Graça, and R.B. Bassanezi. 2007. "Citrus huanglongbing: the pathogen and its impact." *Plant Health Progress* 6:1-18.

Hodges, A., M. Rahmani, and D. Mulkey. 2010. "Economic Impacts of the Florida Citrus Industry in 2003-04."

Hodges, A., and T. Spreen. 2012. "Economic impacts of citrus greening (HLB) in Florida, 2006/07–2010/11." *Electronic Data Information Source (EDIS) FE903*:32611.

Hu, J., and N. Wang. 2016. "Evaluation of the spatiotemporal dynamics of oxytetracycline and its control effect against citrus Huanglongbing via trunk injection." *Phytopathology* 106:1495-1503.

Irey, M., T. Gottwald, M. Stewart, and H. Chamberlain (2008) "Is it possible to replant young groves in an area with endemic HLB: a hierarchical sampling approach to determine infection." In *Proc. Int. Res. Conf. Huanglongbing.* pp. 116-117.

Johnson, E., and J. Graham. 2015. "Root health in the age of HLB." *Citrus Ind* 98:14-18.

Jorgenson, D.W., and C.D. Siebert. 1968. "Optimal capital accumulation and corporate investment behavior." *Journal of Political Economy* 76:1123-1151.

Kalaitzandonakes, N.G. 1992. "Investment decisions and supply response for perennial crops: The case of Florida citrus."

Kompas, T., and T. Che. 2009. "A practical optimal surveillance measure: The case of papaya fruit fly in Australia." *Australian Centre for Biosecurity and Environmental Economics, Crawford School of Economics and Government, Australian National University, Canberra, ACT*.

Lee, J. "Exchange Rates and Foreign Demand for U.S. Fresh Grapefruit."

Lewis-Rosenblum, H., X. Martini, S. Tiwari, and L.L. Stelinski. 2015. "Seasonal movement patterns and long-range dispersal of Asian citrus psyllid in Florida citrus." *Journal of Economic Entomology* 108:3-10.

Manjunath, K., S. Halbert, C. Ramadugu, S. Webb, and R. Lee. 2008. "Detection of 'Candidatus Liberibacter asiaticus' in Diaphorina citri and its importance in the management of citrus huanglongbing in Florida." *Phytopathology* 98:387-396.

Modigliani, F., and M.H. Miller. 1958. "The cost of capital, corporation finance and the theory of investment." *The American economic review* 48:261-297.

Morris, A., and R. Muraro. 2008. "Economic evaluation of citrus greening management and control strategies." *University of Florida*.

Morris, A., R.P. Muraro, and W.S. Castle. 2011. "Optimal grove replanting to mitigate endemic HLB." *Citrus Ind* 92:12-16.

Moss, C.B., and A. Schmitz. 2014. "A Model of the Epidemiology of Greening in Florida Citrus Groves and Its Economic Implications." Paper presented at Pests, Germs and Seeds: The Economics of Policies, Programs, and Technology for Managing Agricultural Pests and Diseases. Davis.

Muraro, R. 2004. *Average Packing Charges for Florida Fresh Citrus, 2002-2003*: University of Florida Cooperative Extension Service, Institute of Food and ….

---. 2010. "Costs of Managing HLB and Citrus Black Spot." *Citrus Expo*.

Muraro, R.P., T.H. Spreen, and M. Pozzan. 2003. *Comparative costs of growing citrus in Florida and Sao Paulo (Brazil) for the 2000-01 Season*: Citeseer.

Myers, J.H., A. Savoie, and E.v. Randen. 1998. "Eradication and pest management." *Annual review of entomology* 43:471-491.

Neupane, D., C.B. Moss, and A. van Bruggen (2016) "Estimating citrus production loss due to citrus huanglongbing in Florida." In *2016 Annual Meeting, Southern Agricultural Economics Association.* pp. 6-9.

Norberg, R.P. (2008) "Economic importance of Florida citrus." In *US Department of Agriculture-ARS 'SWAT Team'Workshop, April.*

Pana-Cryan, R. 1991. "A Model of the World Market for Fresh and Processed Grapefruit." *Unpublished MS Thesis, Food and Resource Economics Department, University of Florida, Gainesville, FL*.

Perez, A., and S. Pollack. 2003. "Fruit and tree nuts outlook." *USDA-ERS. FTS-304* 28.

Pierre, R., T.H. Spreen, and C.B. Moss. 2006. "Invasive Species and Biosecurity: Cost of Monitoring and Controlling Mediterranean." *Journal of Agricultural and Applied Economics* 38:337-343.

---. 2006. "Invasive species and biosecurity: cost of monitoring and controlling Mediterranean fruit flies in Florida." *Journal of agricultural and applied economics* 38:337-343.

Plotto, A., E. Baldwin, G. McCollum, J. Manthey, J. Narciso, and M. Irey. 2010. "Effect of Liberibacter infection (Huanglongbing or “Greening” disease) of citrus on orange juice flavor quality by sensory evaluation." *Journal of food science* 75:S220-S230.

Rahmani, M., and A.W. Hodges. 2008. "Economic Impacts of the Florida Citrus Industry in 2007–08." *Electronic Digital Information Source (EDIS) FE802, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida*.

Richards, T.J., D.W. Shanafelt, and E.P. Fenichel. 2013. "Foreclosures and invasive insect spread: the case of Asian citrus psyllid." *American Journal of Agricultural Economics*:aat099.

Rogers, M., P. Stansly, and L. Stelinski. "Florida citrus pest management guide: Asian citrus psyllid and citrus leafminer." University of Florida.

Roistacher, C. (1996) "The economics of living with citrus diseases: huanglongbing (greening) in Thailand." In *Proc. 13th Conference of the International Organization of Citrus Virologists (IOCV). University of California, Riverside.* pp. 279-285.

Salifu, A.W. 2013. "Economically optimal management of Huanglongbing in Florida citrus." Dissertation, University of Florida.

---. 2013. *Economically optimal management of Huanglongbing in Florida citrus*: University of Florida.

Services, F.D.o.A.a.C. 2019. *Florida Citrus Statistics 2017-18.*

Sharov, A.A. 2004. "Bioeconomics of managing the spread of exotic pest species with barrier zones." *Risk Analysis* 24:879-892.

Shen, W., J.M. Cevallos-Cevallos, U.N. Da Rocha, H.A. Arevalo, P.A. Stansly, P.D. Roberts, and A.H. van Bruggen. 2013. "Relation between plant nutrition, hormones, insecticide applications, bacterial endophytes, and Candidatus Liberibacter Ct values in citrus trees infected with Huanglongbing." *European Journal of Plant Pathology* 137:727-742.

Singerman, A. 2018. "Cost of Production for Processed Oranges in Southwest Florida, 2016/17." *Food and Resource Economics Department, UF/IFAS Extension. FE1038, University of Florida. February*.

Singerman, A., M. Burani-Arouca, S. Futch, and R. Ranieri. "Harvesting Charges for Florida Citrus, 2016/17." UF IFAS.

Singerman, A., M. Burani-Arouca, and S. H. Futch. 2018. *The Profitability of New Citrus Plantings in Florida in the Era of Huanglongbing*.

Singerman, A., and P. Useche. 2016. "Impact of citrus greening on citrus operations in Florida." *University of Florida/Institute of Food and Agricultural Sciences Extension. FE983*.

Spann, T.M., R.A. Atwood, M.M. Dewdney, R.C. Ebel, R. Ehsani, G. England, S.H. Futch, T. Gaver, T. Hurner, and C. Oswalt. 2010. "IFAS guidance for huanglongbing (greening) management." *Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida*.

Spann, T.M., and M.D. Danyluk. 2010. "Effects of HLB infection on sweet orange fruit size and quality." *Citrus Industry September*:14-16.

Spreen, T.H., R.L. Kilmer, and C.R. Pitta. 2007. "Nonhomogeneous products and the law of one price." *Agribusiness: An International Journal* 23:407-420.

Spreen, T.H., and M.L. Zansler. 2016. "Economic analysis of incentives to plant citrus trees in Florida." *HortTechnology* 26:720-726.

Stohlgren, T.J., and J.L. Schnase. 2006. "Risk analysis for biological hazards: what we need to know about invasive species." *Risk Analysis* 26:163-173.

Takayama, T. "Spatial and temporal price and allocation models."

Trejo-Pech, C.J., T.H. Spreen, and M.L. Zansler. 2018. "Is Growing Oranges in Florida a Good Investment?" *American Journal of Agricultural Economics* 100:625-639.

USDA-FAS. "Citrus: World Markets and Trade." February 2019.

USDA-NASS. "Citrus Summary 1997-98." January 1999.

---. "Citrus Summary 2016-2017." August 2017.

---. "Commercial citrus inventory." August 2018.

---. 2018. "Florida Citrus Statistics 2016-2017." *Florida Department of Agricultural Services*.

White, G.B. 1988. "The economic feasibility of vinifera grape production: a net present value analysis." *Journal of ASFMRA*:21-30.

Whitney, J.D. (1995) "A review of citrus harvesting in Florida." In *ASME 1995 Citrus Engineering Conference.* American Society of Mechanical Engineers, pp. 33-59.

BIOGRAPHICAL SKETCH

Carlos R. Pitta is an economist born in Xalapa, State of Veracruz, Mexico, where he got a bachelor's degree in economics at University of Veracruz. After doing some graduate studies at Pontifical Catholic University in Chile, he finished a Master of Science at University of Florida. He has been either assistant, adjunct or visiting professor at the following universities: University of Veracruz at Xalapa, Mexico; American University at Asuncion, Paraguay; Pontifical Catholic University at Lima, Peru; University of Concepcion at Concepcion, Chile; Diego Portales University at Santiago, Chile; University of Florida at Gainesville, USA. In 2015 he resumed a PhD in food and resource economics at University of Florida. His current appointment is assistant professor of economics at the Business School of Austral University, Chile, where he has been academic secretary and acting chair. His current research interests are behavioral and experimental economics, applied microeconomics and statistical methods. He currently lives in Puerto Montt, Chile, one of the southernmost metropolitan areas of the world.