Journal of International Business and Economy (2015) **16** (1): 36-56 (21 pages)

JIBE
Journal of International Business and Economy

Maria Elena Vera Villagran, L. Myriam Sagarnaga Villegas, José M. Salas Gonzalez, and Juan A. Leos Rodriguez

ASSESSMENT OF CITRUS KEY LIME PRODUCTION SUPPLY, EXPORTS AND DOMESTIC DEMAND IN MEXICO BEFORE AND THROUGH THE THREAT OF CITRUS GREENING (HLB)

ABSTRACT

This project looks for the relationship among variables influencing Mexican key lime supply and demand in the domestic and US market under the scenario of using a higher quantity of fertilizers as a strategy for responding against the threat of citrus greening (HLB). With the help of domestic and international databases from 2000 to 2012, a simultaneous equations model was built capturing behavioral and technical variables influencing supply and demand. The most important relationships among variables were price of the product and disposable income for the demand and use of fertilizers and exchange rate for the supply. This work gives the insight, from the economic point of view, that building a model including the right key variables will give a sense of the general structure of a market and the changes in stability due to a sanitary threat

Key Words: Mexican citrus, key lime, supply, demand, econometrics, Mexico-US

Maria Elena Vera Villagran, L. Myriam Sagarnaga Villegas, José M. Salas Gonzalez, and Juan A. Leos Rodriguez
Canter for the Economic, Social and Technological Research on Worldwide Agroindustry and Agriculture (CIESTAAM), Universidad Autónoma Chapingo MX

Correspondence: Maria Elena Vera Villagran
CIESTAAM, Universidad Autónoma Chapingo, Texcoco, 56230, México
E-mail: elenverav@gmail.com
Tel: 52 1 55-1800-2070
Fax: 5255-595-952-16-69

Journal of International Business and Economy
Spring 2015

First Received: Oct. 09 2014
Final Revision Accepted: Jun. 8th 2015

INTRODUCTION

For the last 20 years, the United States of America (US) has been the world first importer of citrus limes, which include the species Citrus aurantifolia Swingle, or better known as key lime or Mexican lime (FAO, 2012; Baldwin and Jones, 2012). This is because citrus productions in the states of Florida, Texas and California were severely diminished after harsh climatic events in these three states. In the last two decades, Mexico has been the main provider for such crops (Baldwin and Jones, 2012). Persian lime is the main Mexican export citrus lime considering volume and production. Mexican key lime had not enjoyed the same market because of phytosanitary barriers that were imposed 20 years ago into key lime production. These barriers were overcome, opening opportunities to Mexican key lime producers in the US markets. However, since 2009, citrus greening or Huanglongbing (HLB) was first detected in Mexico and it has been affecting citrus production, especially the Mexican key lime (SENASICA, 2012; NAPPO, 2012, USDA-APHIS 2012). HLB has been, in the last century, the most damaging disease worldwide detected in all species of citrus (orange, lime, lemons, grapefruit, mandarin and tangerine). HLB emerged in 2004 and 2005 in Brazil (Colleta Filho *et al.*, 2004; Teixeira *et al.*, 2005) and the US (Halbert, 2005), respectively, the two largest orange citrus-growing countries worldwide (Bové, 2006; Gottwald, Da Graça, and Bassanezi, 2007). Citrus greening makes trees die because of lack of nutrition lasting about five years since first detected as symptomatic. During the process of disease deterioration, the citrus trees' yield lessens progressively. So, losses on diminished yields are up to 20% (Bové, 2006). Citrus producers' phytosanitary measures have changed cultural activities, using much more pesticides and increasing the use of fertilizers, and these have been the causes for strong increments in costs (Salifu et al., 2012; Roka, 2011). Foliar applications of micro-nutrients constitute a strategy being employed by an increasing number of Mexico and Florida citrus growers to mitigate HLB debilitating effects (Roka, 2011). All these nutrients and macro-nutrients mentioned in this document are the sources of information for prices in order to build the variable fertilizers in the model. The main objective is to identify relationships among explanatory variables through a simultaneous equations model for the Mexican citrus key lime supply and demand taking in consideration the domestic and US market, such as production, prices, exports, exchange rate and consumption from 2000 to 2012.

LITERATURE REVIEW

This document looks for the variables' relationship for defining supply and demand in citrus key lime in the Mexican domestic and US markets, analysing commercial relationships and building an econometric model consisting in simultaneous equations (Loria, 2011; Hill, Griffiths, and Guay, 2011). The foundation of this analysis is the economic theory which integrated the macroeconomic scenario with microeconomic variables of the decision making process, while integrating the demand equation from the consumers perspective and the supply equation from the citrus growers perspective. Other works that look for the relationship among variables between supply and demand using simultaneous equations models can be found in many arenas of the econometric knowledge, but in the grounds of the Mexican citrus lime agriculture, they are explanatory works about supply, demand, exports and imports especially of Persian lime, the closest substitute for Mexican citrus key lime. The mentioned articles are as the one authored by Sánchez-Torres *et al.* (2011). In this paper, they built their model under the assumption that the citrus lime market offers a real capacity for expansion to the Mexican growers of this crop, therefore, they formulated a multiple regression model, considering the income, exchange rate (peso/dollar), unit import price and the demand of imports, estimated by the method of Ordinary Least Squares (OLS), with annual data from 1994-2008. There are also references from the descriptive papers on the citrus lime markets from the paper written by Schwentesius Rindermann and Gómez Cruz (2005) or the one prepared by Espinosa-Solares and Santoyo-Cortes (1993). However, the purpose of the present work is motivated by a practical situation under an actual threat in order to capture part of the trend on supply and demand. In the matters of modelling an agricultural market, Choi (2010) in his study used a similar methodology to the one used in this paper. His paper was concerned on how to model an agricultural market, how to analyse the impacts of a certain event (*i.e.*, animal disease outbreak) on the beef market, and what the relationships between different variables and its influence are on this market. Based on the review of these specialized papers, the main variables for modelling the Mexican citrus market are Mexican key lime price, production in tons and exports to the United

States, Persian lime price and consumption in Mexico between 2000 and 2012. The model was built using several databases such as the ones kept by Food and Agriculture Organization (FAO), SNIIM, BANXICO, BIE from INEGI and SIAP from SAGARPA. The Hypothesis states if key lime producers are sensitive to key lime price, fertilizer price fluctuations and domestic and international market environment, then the supply and demand curves will be modified by this behaviour.

This paper is divided into the following sections: the introduction and literature review which include a comprehensive review of references either on the key lime market and the information available about the shock created by a phytosanitary threat represented by citrus greening (HLB). The problem statement is supported by the worldwide research on how to deal with an actual problem like HLB, which decreases productivity diminishing yield and, in order to compensate, citrus growers increase one of the elements they have control on, such as fertilizers. This decision would affect first at the microeconomic level but later the macroeconomic scenario. The established economic scenarios can give an overall view on how supply and demand in the citrus key lime market can be modified when citrus growers take a decision in order to solve a problem and consumers have to deal with the cost of such decision as the final recipient of the shock in the supply curve. In order to get all of this done, at the end of this first section a main objective is stated which keeps the purpose of identifying relationships among explanatory variables through a simultaneous equations model for the Mexican citrus key lime supply and demand, taking in consideration the domestic and US market such as production, prices, exports, exchange rate and consumption from 2000 to 2012. The data and methodology section is about establishing the methods and procedures used to accomplish the objective. They mainly consist of building and describing the database structure for the used variables according to recognized econometrics' techniques. The findings section of the paper presents all the outputs, results and discussion obtained from the methodology. The fifth section is conclusion which states that after applying the methodology and examining the results through the analysis of the data, it was accomplished identifying relationships among explanatory variables for the key lime supply and demand such as production, prices, exports, exchange rate and consumption from 2000 to 2012.

DATA AND METHODOLOGY

To accomplish the objective, several activities were done. First of all, to build and describe the database structure for the used variables and from here, the supply and demand model was assembled by, including both, the domestic and the US market. An econometric model of which variables were determined simultaneously based on the exogenous variables interaction influencing the market and the endogenous variables determined by the model was integrated. (Loria, 2011; Gujarati and Porter, 2010; Choi, 2010) The simultaneous equation model looked for a good representation among production, exports and consumption variables.

The sources of information for the model were: the Integrated Markets Information Service from the Mexican Ministry of Economy (SNIIM) for obtaining national and international prices, the Mexican National Institute for Informatics, Geographic and Statistics (INEGI). Production and exports data are taken from the international agency Food and Agriculture Organization (FAO). Exchange rate was taken from the Bank of Mexico (BANXICO). Exports databases were taken mainly from those products sent from Mexico to the United States, since this is the most attractive market for the modern key lime grower. The methodology proposed by Gujarati and Porter (2010), and taken by Choi (2010), was used in this document to prove the hypothesis. In simultaneous models, there is more than one equation for every variable, one per each mutually dependent variable. Parameters were estimated to these models by taking the given information for the overall equation obtained to describe the system.

Variables included were:

- Plm = Key lime price in Mexican distributions centers all over the country
- Plp = Persian lime price in Mexican distributions centers all over the country
- Fer = Fertilizers price
- Csmap = Consumption
- Exp = Exports Volume to the United States
- TCN = Nominal Exchange rate
- TCR = Real Exchange rate

- Ydisp = Disposable Income

Once databases were built, a Pearson correlation coefficient was obtained to find out which variables would have a greater impact on key lime demand and supply. Likewise, the rest of the variables were taken in nominal and real values to pick the best fit for the economic model. At the end, real variables were chosen because they explain best the fit and adjust of the model.

$$\rho_{XY} = \frac{\sigma_{XY}}{\sigma_X \sigma_Y} = \frac{E\,[(X - \mu_X)(Y - \mu_Y)]}{\sigma_X \sigma_Y}$$

Where:

- ρ Pearson coefficient
- $\sigma_X \sigma_Y$ covariance *(X,Y)*
- σ_X standard deviation for variable X
- σ_Y standard deviation for variable Y

Most of the Mexican citrus growers in the agricultural food sector make their selling decision on the current price and yesterday's price in the central distribution centers. Therefore, a one day lagged variable was included in the model to capture this decision making process.

Prices were considered the most influential variable on the model because this is the trigger to the decision of supplying more or less volume of products into the market. Fertilizers were also considered to be a great influence in the model because this is the variable citrus growers are modifying in order to combat HLB symptoms. Taking remedial applications of nutrients to reduce the effects of HLB are made on sake of prolonging tree health and productivity. However, increasing all type of fertilizers could run the citrus growers out of business because costs would increase significantly. Exchange rate is one more variable that has a great impact on the supply and demand of citrus limes in Mexico's domestic market and the exports market such as the one established in the United States. Real exchange rate was the one used in this model because it gave the best fit. The functional relationship among variables for the key lime supply was defined for the following mathematical expression:

$$Qo_t = f(Plm_t, Plm_{t-1}\ TCR_t, PFer_t, Exp_t\ )$$

Where:

Qo_t = Mexican Key lime supply in kilograms.

$PFer_t$ = Real Fertilizers price applied according to the references in the introduction ($/kg)

Plm_t = Real Mexican Key lime price in the domestic central distribution markets in real value in the current time ($/kg)

Plm_{t-1} = Lagged Real Mexican Key lime price in the domestic central distribution markets in real value in the current time ($/kg)

TCR_t = Real exchange rate for national goods and services compared with those in US.

Exp_t = Exports to the US (kg)

In the supply equation a direct relationship among Mexican key lime supply and price was expected.

$$\frac{\delta Qo_t}{\delta Pc_t} > 0 \qquad \frac{\delta Qo_t}{\delta Pc_t} > 0$$

Meanwhile, a negative relationship between Real exchange rate and the price for fertilizers is expected in this same equation.

$$\frac{\delta Qo_t}{\delta PFer_t} < 0 \qquad \frac{\delta Qo_t}{\delta TCR_t} < 0$$

On the other hand, the demand equation for a normal good has been built with the main variables as the price of the good, the disposable income and the closest substitute's price. Assuming that Mexican citrus key lime behaves as a normal good because it is consumed along with other normal goods, its demand is defined by the market's Mexican citrus key lime price, the consumption, and the Persian key lime price (its closest substitute).

According to the methodology defined by Gujarati and Porter (2010) the functional demand equation would be defined as follows:

$$Qd_t = f\,(Plm_t, Plp_t, Csmap_t, Ydisp_t)$$

Where:
Qd_t = Mexican Key lime demand in kilograms
Plm_t = Real Mexican Key lime price in the central distribution markets in real value in the current time ($/kg) in the current time
Plp_t = Real Persian Key lime price in the central distribution markets in real value in the current time ($/kg) in the current time
Yd_t = Real National disposable income ($).

In the supply equation a direct relationship among Mexican key lime supply and price was expected.

$$\frac{\delta Qdo_t}{\delta Pc_t} > 0 \qquad \frac{\delta Qdo_t}{\delta Pc_t} > 0$$

Meanwhile, a negative relationship between Real exchange rate and the price for fertilizers is expected in this same equation. A negative relationship is expected in the demand function.

$$\frac{\delta Qd_t}{\delta Plm_t} < 0$$

Meanwhile, demand quantity and Persian key lime price relationship is expected to be positive because Persian key lime is a good that is substituting key lime.

$$\frac{\delta Qd_t}{\delta Plp_t} > 0$$

Since Mexican citrus key lime is assumed as a normal good, quantity demand is expected to increase when consumer income increases; the same is expected when looking at quantity demanded and consumption.

$$\frac{\delta Qd_t}{\delta Yd_t} > 0$$

$$\frac{\delta Qd_t}{\delta Csmap_t} > 0$$

Structural and reduced form of the model

Model structure

Citrus key lime supply and demand are developed in this section on the basis of empirical knowledge and theoretical information. For each used variable, it is described the data structure and how they fit into the supply and the demand equation. The chosen variables come from the commodity market such as citrus key lime prices, fertilizer prices, volume of production, volume of citrus limes exports and exchange rate for the supply side of the equation. On the other hand, chosen variables for the demand equation are also prices for the closest substitute and disposable income.

As stated above, the model chosen in this analysis is a simultaneous equations model. This model was built based on the methodology according to Gujarati and Porter (2010) and described also by Loria (2011). In these models, variables are sorted into endogenous and exogenous variables. The model determines endogenous variables, while exogenous variables are determined by external conditions. These variables are also identified as predetermined variables and they are independent from the error terms of the model and satisfy the independent variables condition within a classic linear regression model (Gujarati and Porter, 2010).

Demand and supply equations are characterized by sharing prices of the product that is the same endogenous variable. Since there are no correlations among explaining variables as stated in the Linear regression classic model (Gujarati and Porter, 2010), then the best fit for highly affected data by price and the offered quantities is the simultaneous equations model.

On the demand side, endogenous and exogenous variables stated for modeling the citrus key lime market are the following:

Endogenous variables for model Yi

Qdt = citrus key lime demand Volume in kg and obtained from consumer consumption
Qot = citrus key lime supply in kilograms obtained from total key lime national production plus imports volume.
Plm_t = citrus key lime price ($/kg) in real terms in the current period.

Exogenous variables for Xi

Plm_t = Key lime price ($/kg) in real terms in the current period in the domestic market.
Plm_t = Key lime price ($/kg) in real terms in the current period in the US market.
TCR_t =Exchange rate:
Plp_t = Persian lime price ($/kg) in real terms
Yd_t National disposable income ($) in real terms

The structure of the model is as follows:

$$Q_{O_{1t}} = \beta_{1O} + \beta_{11} Plm_{1t} + \gamma_{11} Plm_{1t-1} + \gamma_{12} Exp_{1t} + \gamma_{13} TCR_{1t} + \gamma_{14} Fer_{1t} + \omega_{1t}$$

$$Q_{d_{2t}} = \beta_{20} + \beta_{21} Plm_{2t} + \gamma_{21} Plp_{2t} + \gamma_{22} Yd_{2t} + \gamma_{23} Consmap_{2t} + \omega_{2t}$$

$$Qd_{2t} = Qo_{1t}$$

Coefficients β and γ represent estimated parameters, while ω represents the error term either in the demand or the supply side of the model
Coefficients obtained for each variable on the equation are as follows:

Table 1. Coefficients β and γ for the estimated parameters

Equation	**1**	**Y_1**	**Y_2**	**Y_3**	**X_1**	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**	**X_7**
		Q_d	Q_o	Plm	Plm_{t-1}	Fer	Exp	TCR	Plp	Yd	Consamp
1	β_{10}	1	0	β_{11}	γ_{11}	γ_{12}	γ_{13}	γ_{14}	0	0	0
2	β_{20}	0	1	β_{21}	0	0	0	0	γ_{21}	γ_{22}	γ_{23}

Source: Elaboration through Gujarati's methodology.

Identification

When using a simultaneous equations model it is important to identify every structural parameter within the model (β *and* γ matrix) taking as reference the reduced form of the parameters (π matrix) (Gujarati and Porter, 2010). An equation is not identified when there is not enough information to estimate parameters in the structural form of the equation. A parameter is identified if there are no other parameters that are observationally equivalent. If a parameter is not identified, then the population value of the parameter cannot be deduced by any method with an infinite amount of data. For single equation models, identification fails if the predictor does not vary over observations or if the population covariance of the predictor and the error is not zero. To restore identification, we write the system as if the equilibrium condition allows the replacement of both QD_t and QS_t with Q_t, thereby reducing it to a system of two equations. An equation is over identified when there is more than one possible combination for the estimated parameter values in the structural model.

The sufficient condition for identification is the Rank Condition. For each equation: each of the variables excluded from the equation must appear in at least one of the further equations (no zero columns). Also, at least one of the variables excluded from the equation must appear in each of the further equations (no zero rows). Rank Condition for each equation: the set of variables is considered excluded from the equation. The matrix of coefficients for these variables in the other map of equations must have full row rank.

A structural equation is identified only when the predetermined variables are arranged within the system so as to use the observed equilibrium points to distinguish the shape of the equation under study for which Y_{1t}, Y_{2t} and Y_{3t} are the jointly endogenous variables. The equations in the system are labeled structural equations, as they characterize the economic theory underpinning the determination of each endogenous variable. A variable is endogenous because it is jointly determined (a change in $Y1_t$ leads to a change in $Y3_t$, which in turn leads to a change in $Y2_t$). Exogenous variables may appear in all equations, witness $X1_t$ as to what is endogenous and what is exogenous, why that depends on the scope of the partial equilibrium model under study. To verify the order condition, it is recognized that there are three predetermined variables in the system ($X1_t$, $X2_t$, $X3_t$) and no more than three slope coefficients in any one equation. To verify the rank condition, it was used the following table, in which indicates a variable appears in the given equation and 0 indicates a variable does not appear in the given equation:

Table 2. Level of identification

Equation	M	M	K	K	K-k	m-1	Identification
1	3	2	6	3	3	1	Over identified
2	3	2	6	3	3	1	Over identified

Source: Elaboration through Gujarati's methodology.

A structural equation is identified only when the predetermined variables are arranged within the system so as to use the observed equilibrium points to distinguish the shape of the equation under study. Both equations are over identified therefore, for obtaining the parameters the two stages least squares model is the best fit accordingly to the rank condition.

With regard of error term violations multicollinearity tests are done to verify that error term conditions are not violated such as correlation matrix, heterocedasticity tests and autocorrelation test (Durbin Watson).

Also for testing for multicollinearity, the Condition Number procedure (Judge *et al., 1985)* was revised as an optional way to probe that the error terms conditions were not violated. Under this methodology, the condition number (χ) is the condition index with the largest value; it equals the square root of the largest eigenvalue (λmax) divided by the smallest eigenvalue (λ min). As stated earlier, the two stage least squares model is the procedure used for the structural form of the model because it is a very good fit for over identified equations (Choi, 2010; Loria 2011). The econometric program SAS is used for all related calculations.

FINDINGS

All the data series were first tested with the Dickey-Fuller test for a unit root test and were found free of a unit root in the analyzed data at the value of t stated as critical. We then search for the existence of correlation in the variables. The correlation matrix is one of the first outcomes analyzed after running the SAS® program. The most relevant interactions are among Mexican citrus key lime price and exports, exchange rate and fertilizers price according to table 3.

Table 3: Correlation matrix

	TCR	**QLimes**	**PLm**	**PLm1**	**PLp**	**Exp**	**Consm Ap**	**PFer**	**Ydisp**
TCR	1	0.70179	0.83883	0.67418	0.7452	0.86636	-0.1257	0.57388	0.87767
		0.0075	0.0003	0.0162	0.0035	0.0001	0.6824	0.0403	<.0001
	13	13	13	12	13	13	13	13	13
Qlimes	0.70179	1	0.58042	0.73195	0.70674	0.83094	0.1118	0.74051	0.84666
	0.0075		0.0375	0.0068	0.0069	0.0004	0.7161	0.0038	0.0003
	13	13	13	12	13	13	13	13	13
PLm	0.83883	0.58042	1	0.84466	0.93055	0.76885	0.08296	0.52359	0.83184
	0.0003	0.0375		0.0005	<.0001	0.0021	0.7876	0.0663	0.0004
	13	13	13	12	13	13	13	13	13
PLm1	0.67418	0.73195	0.84466	1	0.92855	0.67517	0.4014	0.61521	0.78471
	0.0162	0.0068	0.0005		<.0001	0.016	0.1959	0.0332	0.0025
	12	12	12	12	12	12	12	12	12
PLp	0.7452	0.70674	0.93055	0.92855	1	0.75057	0.32517	0.62727	0.87363
	0.0035	0.0069	<.0001	<.0001		0.0031	0.2783	0.0217	<.0001
	13	13	13	12	13	13	13	13	13
Exp	0.8664	0.83094	0.7689	0.6753	0.7506	1	-0.24686	0.5655	0.94003
	0.0001	0.0004	0.0021	0.016	0.0031		0.4162	0.044	<.0001
	13	13	13	12	13	13	13	13	13
Consm Ap	-0.1257	0.11180	0.0829	0.4014	0.3252	-0.2469	1	0.2102	-0.0158
	0.6824	0.7161	0.7876	0.1959	0.2783	0.4162		0.4907	0.9591
	13	13	13	12	13	13	13	13	13
PFer	0.5739	0.74051	0.5236	0.6152	0.6273	0.5655	0.21017	1	0.66891
	0.0403	0.0038	0.0663	0.0332	0.0217	0.0440	0.4907		0.0124
	13	13	13	12	13	13	13	13	13

Table 3: Correlation matrix

	TCR	QLimes	PLm	PLm1	PLp	Exp	Consm Ap	PFer	Ydisp
Ydisp	0.8777	0.8466	0.8318	0.7847	0.8736	0.9400	-0.01580	0.6689	1
	<.0001	0.0003	0.0004	0.0025	<.0001	<.0001	0.9591	0.0124	
	13	13	13	12	13	13	13	13	13

In table 2, 3 and 4, the results of the estimation of the model of simultaneous equations are shown.

Table 4: Variables used in the model basic statistics

Variable	N	Mean	Standard deviation	Add	Least	Maximum
TCR	13	10.96077	1.2933	142.49	9.34	13.5
Qlimes	13	1846969	241800	24010600	1367500	2242540
PLm	13	5939	1973	77203	3834	10019
PLm1	12	5687	1829	68239	3834	10019
PLp	13	4399	1987	57182	2454	9030
Exp	13	354318	100359	4606135	217679	487085
ConsmAp	13	2774829	927141	36072772	1955843	5252302
PFer	13	5126	1268	66634	3483	7057
Ydisp	13	923238148	302407648	1.2E+11	454814942	1.4E+10

Here are the Mexican key lime Supply and demand equations

Supply

$$Q_{O_{1t}} = \beta_{10} + \beta_{1t}Plm_{1t} + \gamma_{11}Plm_{1t-1} + \gamma_{12}Exp_{1t} + \gamma_{13}TCR_{1t} + \gamma_{14}Fer_{1t} + \omega_{1t}$$

$$Q_O = -5461.34 - 0.6124Plm_{1t} + 0.000939Exp + 774.65TCR - 0.174Fer$$

R^2=0.8567

Demand

$$Q_{d_{2t}} = \beta_{20} + \beta_{21}Plm_{2t} + \gamma_{21}Plp_{2t} + \gamma_{22}Yd_{2t} + \gamma_{23}Consmap_{2t} + \omega_{2t}$$

$$Q_d = 907926.3 - 75.29Plp_{1t} + 0.000111\ Y_{d\,isp1t} + 0.08735\ Consamp_{1t}$$

R^2=0.7791

The expected signs on the variables are obtained for the Mexican citrus key lime price, exchange rate and for the lagged price according to these equations. Estimated coefficients on fertilizers price are not as strong as they could be expected, therefore they may need a fine calibration in order to display the production decisions better. The results obtained in the supply function are reflecting the scenario before HLB, therefore, it could be expected an increase among all the costs of production, which compromises fertilizers, management practices, used machinery and labor. It is assumed that the relationship between price of key lime and fertilizers will influence citrus growers decisions more importantly in later observations. The results obtained by Sánchez-Torres et al. (2011) in her citrus supply model found a similar relationship while obtaining the citrus supply function because her data are also reflecting the scenario before HLB. In the paper by Choi (2010), there is also an assumption in his simultaneous equations model about a sanitary threat jeopardizing the beef market on the supply side. The model reflects the shift on the supply equation and the likely scenario on the price.

The expected signs in the lagged variable show the producer's speculative behavior. Therefore, if the price of Mexican citrus key lime was low the day before or the previous period, it is expected to increase in the following day or season until oversupply and price decreases again.

Nevertheless small inconsistencies found in the estimation of the model, the supply function shows a relevant price behavior in the current period and correlated to exchange rate. This is the result of rational key lime growers responding to the international citrus market behavior who use the information as the basis of their production decisions. The choice is to cut or not during the 2 to 4 weeks harvesting time accordingly to the geographic region.

On the other hand, the Exchange rate (TCR) variable mirrors the importance of Mexico in the international Limes and Lemons' market and also allows introducing a very relevant external factor to the model. TCR also influences the supplied quantity in the domestic market when there is a market shock in international exchange rate. This variable is also able to mirror the influence of current phytosanitary barriers, which have been a great issue to overcome when exporting Mexican key lime. Besides, TCR and Exports also are means to measure world trade openness and competitiveness in the citrus industry operations.

As mentioned earlier and related with tests done to probe violations to the error term, it is found that multicollinearity is the only one that is positive. The rest of the tests results are negative (heterocesdaticity and Durbin Watson). There is not a multicollinearity corrective treatment because all the chosen variables are essential for the built of the model. Analyzing furthermore multicollinearity is expected because many productive and market factors influence one another in different arenas. Therefore, the variables with the greatest correlation have the highest standard errors (Table 1).

The violations to the assumptions to the error term have to do with residuals are not correlated serially from one observation to the next. This means the size of the residual for one case has no impact on the size of the residual for the next case. The Durbin-Watson Statistic is used to test for the presence of serial correlation among the residuals. The value of the Durbin-Watson statistic ranges from 0 to 4. As a general rule of thumb, the residuals are uncorrelated is the Durbin-Watson statistic is approximately 2. A value close to 0 indicates strong positive correlation, while a value of 4 indicates strong negative correlation (Gujarati and Porter, 2010).

The output from SAS shows under the PROC REG instruction and Model 1 a Durbin Watson of 2.647. Once the program is fixed to run the simultaneous equation model, the output shows that the Demand equation has a Durbin Watson of 2.03 and the Supply equation has a Durbin Watson of 2.073. So, according to Gujaraty et al (2010) and taking the DW = 2 as reference, there is not positive or negative autocorrelation, therefore there are no violations to the assumptions to the error term.

According to Judge et al. (1985) and Allison (2012) multicollinearity is a common problem when estimating linear or generalized linear models, including logistic regression models. It occurs when there are some kinds of relationships among predictor variables, leading to unstable estimates of regression coefficients. Most data analysts assume that multicollinearity is not desirable. According to Judge (1985), high multicollinearity is a multiple correlation coefficient greater than

80%, but in many cases there are several situations in which multicollinearity can be safely ignored because of the characteristics of the database and the variables. In this case, the demand equation is kind of affected by multicollinearity because of the low statistical significance in its explicative variables.

The output shows that Mexican citrus key lime Price is inversely related to the demand equation and the Persian key lime price behaves as a commodity substitute. On regard of disposable income, key lime behaves as a normal good because as a meat flavor enhancer in the taste of the Mexican consumer and also to the consumer that looks for citrus key lime in the United States.

CONCLUSION

As expected and through the analysis of the data, this study was accomplished by identifying the relationships among explanatory variables for the key lime supply and demand such as production, prices, exports, exchange rate and consumption from 2000 to 2012. The simultaneous equation model methodology is pertinent to finding relationships among endogenous and exogenous variables. This methodology is also appropriate to capture behavioral and technical relationships among the variables that are influencing the supply of key limes such as fertilizers supply for growing citrus key lime trees. Economic theory in this case provides the basis for theoretical reasoning to explain the behavior and trend among these variables relationships. In this case, a practical approach taken by the US and Mexican citrus growers to deal with a citrus sanitary threat and how these interactions exist is depicted in a simultaneous model. While in the supply side citrus growers are increasing fertilizers consumption through applying an intensive foliar and ground fertilization strategy in an attempt to deal with a citrus disease, and in the other hand how the demand side is affected by the increased price of citrus lime because of the increased costs of using higher amounts of fertilizers.

It was found that the most important relationships among variables were price of the product and disposable income for the demand and use of fertilizers and exchange rate for the supply. The expected signs on the variables were obtained for the Mexican citrus key lime price, exchange rate and for the lagged price according to these equations. Estimated coefficients on fertilizers prices were not as strong as they could be expected, may be because there is a high quantity of components in these variables, therefore they may need a fine calibration in order to display the citrus growers' production decisions better. The expected signs in the lagged variable showed as expected the producer's speculative behavior. Consequently, the price of Mexican citrus key lime was behaving in anticipation to being low the day before and increasing the following day until oversupply and price decreases again. This is the way of inferring the rational of key lime growers responding to the citrus market behavior who use the information as the basis of their production decisions. Though the minor inconsistencies are found in the estimation of the model, the supply function showed a relevant price behavior in the tested term and correlated to exchange rate. The Exchange rate (TCR) variable mirrors the importance of Mexico in the Limes and Lemons' international market and also allows introducing a very relevant external factor to the model. TCR also influences the supplied quantity in the domestic market when there is a market shock in international exchange rate. This variable is also able to mirror the influence of current phytosanitary barriers, which have been a great issue to overcome when exporting Mexican key lime. Besides, TCR and exports are also the means to measure world trade openness and competitiveness in the citrus industry operations.

In conclusion, it was found that the Mexican key lime demand quantity was affected mainly by the market key lime price, Persian lime price and disposable income. The output showed that Mexican citrus key lime Price is inversely related to the demand equation and the Persian key lime price behaved as a commodity substitute. Regarding to disposable income, key lime behaved as a normal good as a meat flavor enhancer for the taste of the Mexican consumer and also as the substitute for consumer that looks for citrus key lime in the US. The Mexican key lime quantity offered in the 2000-2012 period is mainly affected by the key lime price and the exchange rate and in a lesser degree by fertilizers' price but not as expected because this last variable has many elements such as the time HLB was detected by first time, the time the citrus growers began to apply more fertilizers and account this change in increased prices. Therefore, we failed to reject the hypothesis on whether key lime producers are sensitive to key lime price and fertilizer price fluctuations. In order to have more tools to expose this behavior, it is important to recalibrate the mechanisms inside the model to transfer the performance of the variable fertilizer price to more accurately reflect the use of these chemicals in the strategy against citrus greening (HLB) on the supply side of the simultaneous equation model. Interviewed growers through direct surveys have manifested the increased use of fertilizers in their orchards to compensate HLB damage on citrus trees. Therefore, the supply function has to show the heavier use of this supplement. The citrus growers' rational decision based on reliable international market information has been fulfilled because Mexico so far has been the main provider of lime and lemon to the United States during the last three decades.

From the economic point of view, the impact of a sanitary threat such as citrus greening (shock on the supply side) can devastate the production of citrus and diminish dramatically the supply curve. Therefore building models with the right key variables allow to have a sense on market price and quantity ex ante and ex post, and how these evolve over time in order to improve the decision making process of every stakeholder involved in the industry and public policy designers.

REFERENCES

Allison, P. 2012. *When can you safely ignore multicollinearity*? http://www.statisticalhorizons.com/multicollinearity.

Banco de México (BANXICO - Bank of Mexico). *Exchange rate and auctions historical data CF372*. Daily and Monthly historical series (from April 1999 to October 2013), exchange rate (pesos per dollar), http://www.banxico.org.mx/SieInternet/consultarDirectorioInternetAction.do?accion=consultarCuadro&idCuadro=CF372&sector=6&locale=es.

Baldwin, K. L. and K. G. Jones. 2012. *U.S. citrus import demand: Seasonality and substitution*. In Southern Agricultural Economics Association Annual Meeting, Birmingham, AL, February 4-7, 2012. http://ageconsearch.umn.edu/bitstream/119741/2/SAEA%20citrus%20final.pdf.

Bové, J. M. 2006. Huanglongbing: A destructive, newly-emerging, century-old disease of citrus. *Journal of Plant Pathology* 88: 7-37.

Coletta-Filho, H. D., M. L. P. N. Targon, M. A. Takita, J. D. De Negri, J. Jr. Pompeu, M. A. Machado, A. M. Amaral, and G. W. Muller. 2004. First report of the causal agent of huanglongbing (Candidatus Liberibacter asiaticus) in Brazil. *Journal of Plant Disease* 88: 1382. http://dx.doi.org/10.1094/PDIS.2004.88.12.1382C.

Choi, C. 2010. *An analysis on agricultural market behavior*. Office of Graduate Studies of Texas A&M University.

Espinosa-Solares, T. and V. H. Santoyo-Cortes. 1993. *The Persian lime market in Mexico.* (*El mercado del limón persa en México*). Texcoco, Mexico: Canter for the Economic, Social and Technological Research on Worldwide Agroindustry and Agriculture (CIESTAAM, Centro de Investigaciones Económicas, Sociales y Tecnológicas de la Agroindustria y de la Agricultura Mundial, Universidad Autonoma Chapingo).

FAO (Food and Agriculture Organization). 2012. *Volume of production, exports, key lime prices.* http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#anco.

Gottwald, T. R., J. V. Da Graça, and R. B. Bassanezi. 2007. Citrus Huanglongbing: The pathogen and its impact. *Journal of Plant Health Progress.* http://www.plantmanagementnetwork.org/pub/php/review/2007/huanglongbing/.

Gujarati, D. N. and D. C. Porter. 2010. *Econometrics* (*Econometría*) (5th Ed.). Mexico City: McGraw Hill Interamerican Editores.

Halbert, S. 2005. *The discovery of Huanglongbing in Florida.* Proceedings of the 2nd International Citrus Canker and Huanglongbing Workshop, Orlando, FL.

Hill, R. C., W. E. Griffiths, and C. L. Guay. 2011. *Principles of econometrics* (4th Ed.). New York: John Wiley & Sons, Inc.

INEGI (National Institute of Statistics and Geographic Information, Instituto Nacional de Estadística Geografía e Informática) and BIE (Economics Information Bank, Banco de Información Económica). http://www.inegi.org.mx/sistemas/bie/.

Judge G. G., W. E. Griffiths, R. Carter Hill, L. Helmut, and L. Tsoung-Chao. 1985. *The theory and practice of econometrics* (2nd Ed.). New York: John Wiley & Sons, Inc.

Loria, E. 2011. *Econometrics with applications* (*Econometría con aplicaciones*) (1st Ed.). Mexico City: Editorial Pearson.

North American Plant Protection Organization (NAPPO) Secretariat. 2012. *Diagnostic Protocol, DP 02: Citrus Huanglongbing.* www.aphis.usda.gov/.../downloads/NAPPO_HLB_DP_2_2012-05-30-e.pdf.

Roka, F. M. 2011. *Defining the economic "tipping point" in the management of citrus greening: Follow the standard protocol or shift to an enhanced foliar nutritional program.* Proceedings of the 18th International Farm Management Congress Methven. Canterbury, New Zealand.

Salifu, A. W., K. Grogan, T. Spreen, and F. Roka. 2012. The economics of the control strategies of HLB in Florida Citrus. *Proceedings of the Florida State Horticultural Society* 125: 22–28.

Sánchez-Torres, Y., J. Matus-Gardea, J. García-Salazar, M. Martínez-Damián, and M. Gómez-Cruz. 2011. Estimate of the demand of imports of Persian lime (Citrus latifolia tanaka) in United States provinent from Mexico (1994-

2008) (Estimación de la demanda de importaciones de limón Persa (Citrus Latifolia Tanaka) en Estados Unidos procedentes de México (1994-2008)). *Tropical and Subtropical Agroecosystems* 14(3): 819-827.

SENASICA (Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaría, Mexican National Service for Animal and Plant Health, Food Safety, and Food Quality). 2012. *SENASICA-SAGARPA Campaign against HLB.* http://www.senasica.gob.mx/?id=4512.

SIAP. 2012. Servicio de Información Agroalimentaria y Pesquera (National Bureau on agrifood and fisheries information). 2012. *National statistics on production, exports, key lime rural prices to the citrus grower* (*Estadísticas de producción*, *resumen nacional*). http://www.siap.gob.mx/index.php?option=com_wrapper&view=wrapper&Itemid=369.

SNIIM (National Beaureu on Market Integration and Information, Sistema Nacional de Información e Integración de Mercados- de la Secretaría de Economía). 2012. *Domestic and US markets prices for key lime* (*Precios de limón mexicano en Centrales de Abasto y en Mercados de Estados Unidos de América*). http://www.economia-sniim.gob.mx/NUEVO/Consultas/MercadosNacionales/PreciosDeMercado/Agricolas/ResultadosConsultaFechaFrutasYHortalizas.aspx?fechaInicio=01%2f01%2f2012&fechaFinal=31%2f12%2f2012&ProductoId=423&OrigenId=-1&Origen=Todos&DestinoId=-1&Destino=Todos&PreciosPorId=2&RegistrosPorPagina=500.

Schwentesius Rindermann, R. and M. Á. Gómez Cruz. 2005. Persian lime: Trends in the Mexican market - *Limón Persa. Tendencias en el mercado mexicano.* Texcoco, México: World Bank (Office in Mexico city – Banco Mundial) and Canter for the Economic, Social and Technological Research on Worldwide Agroindustry and Agriculture (CIESTAAM) Centro de Investigaciones Económicas, Sociales y Tecnológicas de la Agroindustria y de la Agricultura Mundial, Universidad Autónoma Chapingo.

Teixeira, D. C., A.J. Ayres, E. W. Kitajima, F. A. O. Tanaka, J. L. Danet, S. Jagoueix-Eveillard, C. Saillard, and J. M. Bove. 2005a. First report of a huanglongbing-like disease of citrus in Sao Paulo State, Brazil, and association of a new liberibacter species, 'Candidatus Liberibacter americanus', with the disease. *Plant Disease Journal* 89 (1): 107.

USDA-APHIS 2012. *Reports on the occurrence of HLB in Mexico by first time.* http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus_greening/downloads/pdf_files/spro/DA-2009-32.pdf.