An Economic Model for Evaluating the Impact of Prohibiting the Use of Copper in Grapefruit Production of Florida.

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ABSTRACT:

This article deals with the economic impact of withdrawing copper from grapefruit production in Florida. A model of the world market for Florida grapefruit is developed as a mathematical programming model and is solved via GAMS using data on yield/pack-out impacts from a National Agricultural Pesticide Impact Assessment Program study. The model is first run with copper included in the production process assuming 2001-02 as the base year to forecast production and on-tree prices of grapefruit for the next nine years. Then, the yield and pack-out impacts without copper are incorporated into the model to look at the changes in forecasted production and on-tree prices.

Without using copper in grapefruit production, on-tree prices increase leading to an increase in grower revenue, decreased fresh marketing and increased prices for domestic and export fresh grapefruit. Consumer prices also increase. Even though the cost of production increases, net revenue to growers using no copper is greater than that when copper is used.

Keywords: Grapefruit, Florida, non-linear programming, efficient market allocation, spatial equilibrium model.

Historically, agriculture and pesticides have a close relationship. Pesticides contribute to agriculture through higher productivity, lower cost of production, resulting in relatively inexpensive and unblemished products to customers. Agricultural policy, which sought to promote land and labor productivity and low food prices for consumers, tended to promote the use of pesticides. But increasingly, environmental concerns have raised issues about the unmitigated use of pesticides and their possible effects on environment quality and human health through its impacts on wildlife and the ecological system, its potential impacts on soil and water quality and its direct impacts on human health. Hence, there exists an inherent conflict between these two policies and this necessitates some regulatory concerns. Agencies such as the United

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State Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) have been charged to administer the provisions of various acts and regulations on pesticide usage. The Food Quality Protection Act (FQPA) of 1996 requires EPA to reassess the tolerances of all pesticides in use by the year 2006 depending on environmental risk and health hazards.

The project has been undertaken for Florida grapefruit production because it accounts for almost 80 percent of U.S. grapefruit production. Even more importantly, it accounts for almost 95 percent of U.S. fresh grapefruit exports (Florida Agricultural Statistics Service (FASS), Citrus Summary 2002-2003). It also accounts for more than one-half of total world grapefruit production. Florida grapefruit represented 2.78 percent of farm cash receipts in Florida in 1997 where all citrus accounts for 22.04 percent and oranges account for 17.87 percent (FASS, 1998). This position Florida grapefruit in the second largest commodity in the citrus sub-sector in terms of cash receipts from farming.

Copper is a pesticide extensively used as a fungicide in the production of grapefruit for controlling diseases such as greasy spot, melanose and scab. It has been found that on average, copper is being used on about 90 percent of fresh grapefruit acreage and about 60 percent of non-bearing grapefruit acreage (NAPIAP-USDA, 1999). The study also provides estimates of the direct impact of copper on grapefruit production in Florida by withdrawing it from the production process and using available alternatives in its place (Table 1).

Therefore, suspending copper and using alternatives in its place has a direct impact on the cost of production in general and decreasing yield and pack-out in some cases. It is also necessary to have an economic model for evaluating the overall economic impact thereon. An economic model for evaluating the impact of prohibiting the use of copper in Florida grapefruit production is developed.

In the process of reassessing pesticide tolerances, the suspension of copper from fresh grapefruit production causes substantial economic impacts in terms of higher cost and lower yield and pack-out which eventually influences (through supply & revenue earned) both domestic and export markets. If copper is withdrawn from grapefruit production and other available alternatives are used instead, the cost of production will be increased and the yield and pack-out will be decreased. This in turn, will influence revenue to producers. Thus, the domestic market as well as export market will be affected.

The objectives of the project are (1) to describe the fresh grapefruit market, both domestic and export, (2) to develop a model that will represent fresh grapefruit marketing, which will include the domestic and export markets and (3) to determine the economic impact of eliminating copper on grapefruit growers.

Pesticide and Grapefruit

Grapefruit is susceptible to diseases such as greasy spot, melanose, scab etc. The pesticides that can be used to control these diseases are benomyl, ferbam, petroleum oil, benlate and copper. Yet as copper successfully controls the above-mentioned diseases in grapefruit production, it's role as a pesticide in grapefruit production maybe eliminated because of a copper buildup in the soil.

As for copper substitutes, a study by an Assessment Team (NAPIAP-USDA, 1999) shows that the use of pesticides as alternatives to copper in the production of grapefruit in Florida leads to an increase in cost of materials and application and in some cases, a decrease in yield and/or pack-out rate. In the study, information on pesticides in use for a specific pest on a specific crop in a specific state are the figures reported by a survey. One or more alternative pesticides are identified for each target pest with a pesticide currently in use. Yield and pack-out impacts are taken from survey data. In order to get the cost impacts, the total cost of use for both current and alternative pesticides are calculated. Thus, the production impacts and the cost impacts are eventually translated into the economic impacts of withdrawing a specific pesticide from use.

To assess such an impact, a multi-market allocation model is developed. The model accounts for the specific characteristics of the fresh and juice grapefruit market. Two main producer regions in Florida with two commodities, white grapefruit and pink grapefruit are included in the model. The yearly production is estimated using data on the number of grapefruit trees and the tree yield based on tree age. The number of trees multiplied by the age related tree yields equals total production. Thus, the production of each tree age group will be summed to get the supply of grapefruit. Then, total supply will be alloocated to fresh and processed markets, both domestic and foreign. The production of seedy grapefruit (being very negligible in quantity) has not been included in the model.

The demand side of the equation consists of five relevant markets, four for fresh grapefruit and one for processed juice. These are the (1) domestic market for fresh white grapefruit, (2) domestic market for fresh red grapefruit, (3) export market for fresh white grapefruit, (4) export market for fresh red grapefruit and (5) the market for processed juice. No distinction is made between juice from white and juice from red grapefruit. Red Seedless and white seedless grapefruit are sold in both the domestic and export markets. The main export markets are Japan, the European Union and Canada. Each market has specific preferences especially with respect to fruit size and external appearance. Pana (1991) used a similar model; however, an explicit specification for the domestic market and export market for processed juice was included. The supply and demand components of each market are integrated through the market equilibrium conditions.

Theoretical Multi-market Equilibrium Model

A market allocation model is developed so as to depict the process of distributing grapefruit production across alternative markets. To simplify the exposition, assume there are two relevant fresh markets for both red seedless and white seedless Florida grapefruit. The derived markets are domestic and export. Let the inverse derived demand in each fresh market at the output door of the packinghouse be

(1) $$P_{vj} = \alpha_{vj} - \beta_{vj} Q_{vj}^{D}$$

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*.

Let the supply X_{vj} be the boxes of variety *v* available to market *j*. The quantity packed for the fresh market is

(2) $$Q_{vj}^{D} = \lambda_{vj} X_{vj}$$

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 (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

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

Since differences in eliminated fruit is mainly cosmetic and not size of the fruit, it's 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.[2] Therefore juice production is given by

(4) $$JP = \sum_v JU\left(\left(\sum_j \left(1-\lambda_{vj}\right) X_{vj}\right) + FR_v\right)$$

where *JP* denotes the single strength equivalent (SSE) gallons of juice produced in a particular season; *JU* is gallons of juice per box (4.8 gallons) that does not vary by variety; and FR_v is the quantity of variety *v* that goes from the grove directly to the processing plant. The inverse derived demand equation (FOB the packinghouse) for grapefruit juice is

(5) $$P_J = \alpha - \beta Q_J$$

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

(6) $$JP = Q_J .$$

Define PD_v as the total boxes of variety *v* in a particular 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

$$(7)\quad \text{Max} \sum_{v}\sum_{j}\int\left(\alpha_{vj}-\beta_{vj}Q_{vj}^{D}\right)dQ_{vj}^{D}+\int\left(\alpha-\beta Q_{J}\right)dQ_{J}-\sum_{v}\sum_{j}PC_{j}Q_{vj}^{D}-PR\,Q_{J}$$

$$(8)\quad s.t.\quad \sum_{j}X_{vj}+FR_{v}\leq\quad PD_{v}\qquad\qquad v = \text{red, white}$$

$$(9)\quad Q_{vj}^{D}\quad\leq\quad\lambda_{vj}X_{vj}\qquad\qquad j = \text{domestic, export}$$

$$(10)\quad Q_{j}\leq\left(\sum_{v}JU\left(\left(\sum_{j}\left(1-\lambda_{vj}\right)X_{vj}\right)+FR_{v}\right)\right).$$

All variables are non-negative.

This model is a multi-market equilibrium model; however, supply is predetermined each season (i.e. supply is perfectly inelastic) and there are no transportation costs. The output markets are FOB the packinghouse. The objective function (equation 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. Thus the 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 new trees to bear fruit. The first constraint (set of equations 8) in the model represents the balance between total derived demand and supply. The 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 next four constraints (set of equations 9) are the balancing constraints between boxes sent to the packinghouse and the boxes actually packed for fresh use. The last constraint (10) balances the juice from the boxes not qualified for the fresh market (elimination) plus the juice from the field run boxes with total consumption of juice. One box of grapefruit produces 4.8 gallons of juice and no storage of juice is considered in the model. The model determines the equilibrium prices and quantities FOB the packinghouse. The model is run taking 2001-2002 as a base year. One derived supply point and five derived demand points (two domestic and two exports 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 considered to be one. The model is run taking 2002-2003 as the based year using actual data from that period and then is to project model results for nine more years.

The mathematical model starts with a supply sub-model based on Pana (1991). After the base year model is run, the tree inventory is updated before the model is run for year two. The total number of trees for year two is determined by adjusting the base year's tree inventory by the number of trees that survived the base year and the number of new trees that were planted in the base year. The age of each tree coming into year two is increased by one year. This process of updating the tree inventory is completed each year before the multi-market equilibrium model is run for the next year.

Data

The yield data for grapefruit trees by age groups are available from the Statistical Reporting Services of USDA. Yield data for different age group have been collected from various issues of the Citrus Summary published by Florida Agricultural Statistics Services (FASS). The data are for the age groups such as 3-5 years, 6-8 years, 9-13 years, 14-23 years and 24 and above years old. Since the data are for a range of age of the trees, it is difficult to have the yield for a tree of particular age. So, the data has been interpolated to get a continuous yield of the trees over age.

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) to be allocated into white or red grapefruit has been minimized by using the percentage of their respective identified numbers. The tree inventory data used in the model has been collected from FASS (2002) publication and unpublished data from department of citrus.

Demand equations for both red and white fresh domestic grapefruit have been estimated using an average price and quantity plus an estimated price elasticity, assuming a linear demand. These equations (domestic red and white fresh grapefruit and also for exports to Canada) are estimated based on an own price elasticity of - 1.67 (Lee). The price elasticity of demand for both fresh red and white grapefruit exported to Europe has been estimated to be -0.39 while that of white and red fresh grapefruit exported to Japan has been estimated to be -0.66 and used in this model (Lee, 2003). The juice price elasticity of demand is -0.4 (Brown).

The pack-out rates are based on a study by Muraro; however, the pack-out rates used in the model were adjusted in order to calibrate the model. The adjusted pack-out rates used are 60.5 percent for red and 58 percent for white U.S. domestic grapefruit as well as exports to Canada, 54 percent for red and 52 percent for white exports to Europe and 48.5 percent for red and 47.5 percent for white exports to Japan.

The processing cost is $0.30 per single strength gallon. Packing cost is $7.50 per box for grapefruit packed for the U.S. and Canadian markets and $8.80 per box for the markets in Europe and Japan (Muraro). The number of red grapefruit boxes sent to different markets is 5,274,000 to the U.S., 1,032,500 to Canada, 3,109,500 to Europe, and 3,074,500 to Japan (Florida Department of Agriculture and Consumer Services). The number of white grapefruit boxes sent to different markets is 277,500 to the U.S., 59,000 to Canada, 160,500 Europe, and 2,539,000 to Japan (Florida Department of Agriculture and Consumer Services). Single strength gallons of juice produced was 148,000,000 gallons and was sold for $0.92 per single strength gallon.

Empirical results

The model with the use of copper is considered to be the base model. The base model is run using actual data from the 2002-03 season as well as historical information from 1945 to 2002, and then simulated for ten more years. Then, it is re-run with the changes in data to reflect a ban on the use of copper. In order to validate the model, assumptions were made regarding the percentage of field run red and white grapefruit. These percentages are based upon estimates found in Brown et al. (1999). In the baseline model nine percent of all red grapefruit and 90 percent of the white grapefruit produced outside of the Indian River region are assumed to be field run. These percentages also reflect that the primary market for fresh white grapefruit is Japan, which is primarily supplied from the Indian River region.

Base results

The base model (with copper) shows a decline in estimated on-tree prices and also in total revenue earned for both red and white grapefruit compared to the base year (Table 1).

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However, they have an increasing tendency over time. The utilization of red grapefruit is very close to production indicating negligible quantities of abandonment. The same is true for white grapefruit in the base model (Tables 1 and 2). The only difference is that abandonment is more in case of white grapefruit. The difference between production and utilization represents the quantity of fruit abandoned. [There is precedence for abandonment of grapefruit in Florida in 1996-97, 1997-98 and 1998-99 seasons.]

Analyzing the production and utilization of red grapefruit in the base model, it is observed that just after the base year (1998-99) there is a jump in production as well as utilization. This is because of the fact that the model uses actual production and utilization figures in the base year. For the other years production and utilization is endogenously estimated.

Production changes are based on the total number of trees (including new plantings), their age composition and respective yields. After the base year, production is projected to increase until 2000-1, and then decline thereafter (Table 1). On the other hand, total tree numbers show a continuous decline throughout the entire period. Utilization increases until 2001-2, and then it declines. On-tree prices are also low even though they are increasing towards the end of the forecast period. Revenue from red grapefruit fluctuates over the forecast period. The fluctuations in revenue largely depend on the quantities utilized and on-tree prices.

For white grapefruit, the base model shows that there is increased production and decreased utilization in 1999-0 compared with the base year's actual figures (Table 2). Production declines throughout the forecast period as the total tree numbers also decline. After the base year, utilization declines for three years and then increases for three years and after that again declines for last two years. The on-tree price declines just after the base year (1999-0), then increases for two years and declines for next two years and after that keeps on increasing for the rest four years. As a result of variations in on-tree prices and utilization, revenue from white grapefruit keeps on declining for four years after the base year, and then increasing for the rest five years of the forecasted period.

The distribution of utilized red grapefruit between fresh and processed categories shows that after the base year both increase (Table 3). However, fresh utilization is static (same) for four years and then it declines over the next five years. On the other hand, processed utilization keeps on increasing for three years and then it declines continuously for the rest of the forecast period. Both fresh and processed utilization of red grapefruit have inverse relationships with their prices.

For white grapefruit, the base model shows that fresh utilization increases just after base year and remains static for five years, keeps on increasing for next two years and then declines for last two years (Table 4). Fresh white utilization is inversely related to price; however, processed utilization of white grapefruit shows declines for three years after the base year and then it increases very little for four years and declines again for last two years. With the decline in processed quantity, price also declines for the first three years after the base year and again with the increase in processed quantity, price also increases for the sixth and seventh years (2004-5 and 2005-6). Of course, for the last two years as well as the fourth and fifth years (2002-3 and 2003-4), processed quantities maintain the inverse relationships with prices.

Alternative results

The alternative model (without copper) shows that the production and utilization of red grapefruit increase for three years after the base year and then it declines for four years and increases for last two years of the forecast period (Table 1). On-tree prices are more or less stable over the period, maintaining a theoretically consistent inverse relationship with utilized quantities. There is a gap between production and utilization indicating abandonment of fruit. In this model some new planting occurs because of relatively high and stable on-tree prices. So, total tree numbers increase continuously starting in 2001-2. Revenue from red grapefruit increases through 2002-3, then it declines for three years and after that it increases for last two years.

For the white grapefruit, production increases for the first year after the base year and then it declines from 2000-1 through 2006-7 and increases a little (negligible) in 2007-8 (Table 2). On the other hand, utilization keeps on declining through 2002-3 and then it increases for four years and decreases for the last year. On-tree prices show inverse relationships with utilized quantities except a little deviation in 2006-7. Due to higher and more or less stable on-tree prices, there are some new plantings even though the total tree numbers decline continuously over the forecast period. Revenue from white grapefruit declines through 2002-3 and then increases for four years and finally it decreases during the 2007-8 season.

Fresh and processed utilization of red grapefruit shows that fresh utilization increases through 2001-2 and declines for the next four years and then again increases for the last two years (Table 3). Fresh prices maintain an inverse relationship with quantities throughout the entire forecast period. On the other hand, processed utilization increases through 2002-3 and declines for next four years, and again increases for the 2007-8 season. But, the processed price remains the same for the entire period. This is because the processed quantity has reached its maximum beyond which it will not be profitable to process the fruit.

For the white grapefruit, fresh utilization is constant over the period with a constant price (Table 4). However, the processed utilization declines through 2002-3, increases for next four years, and finally declines for the 2007-8 season. Processed prices do not maintain the inverse relationships with quantities except for the last year.

Comparison of results

Comparing the results of the two models it is observed that without copper, production and utilization decline, on-tree prices increase and total revenues increase for both red seedless and white seedless grapefruit (Tables 1 and 2). Utilization of red grapefruit declines by 9.42 percent while utilization of white grapefruit declines by 38.19 percent. On-tree prices for red increase by 171 percent where as on-tree prices for white grapefruit increase by 68 percent (Tables 1 and 2).

Without copper fresh utilization of red grapefruit decreases by 45.53 percent while that of white grapefruit decreases by 49.59 percent due to decrease in pack-out rate. But, processed utilization of red grapefruit increases by 32.93 percent while that of white grapefruit decreases by 33.84 percent (Tables 3 and 4). Fresh on-tree prices for red grapefruit increase by 434 percent while fresh on-tree prices for white grapefruit increase by 157 percent without copper. On the other hand, the average processed price for red grapefruit decreases by 27.98 percent while the average processed price for white grapefruit decreases by 19.48 percent.

Impact on producers

The impact on producers can be observed from Table 5 and Table 6. When copper is withdrawn and alternatives are used in its place as shown earlier (Table 1A), there may be two possibilities of per acre cost increase. One is to control scab with benomyl only without using ferbam since it is more costly and is considered to be low cost impact/acre as ($120.27 + 20.34 + 20.19) = $ 160.80. The other is to control scab with both benomyl (50 %) and ferbam (50 %) which will give a high cost impact/acre as to (120.27 + 20.34 + 277.15) = $417.76. In order to get acreage under production, the total tree numbers are divided by per acre tree numbers which are (7,397/70.0) = 111.47 thousands for red grapefruit and (4,397/44.0) = 99.93 thousands for white grapefruit using base year data (Citrus Summary, 1998-99). Then, this estimated acreage is multiplied by the estimated increase in per acre cost giving the total cost impact. The projected increase in cost is subtracted from revenue giving adjusted revenue. The ultimate impact on revenue from the tables shows that there is an increase in net revenue for red grapefruit, but there is a decrease in net revenue for white grapefruit considering only the material and application cost of the alternatives, holding other related costs to be fixed (Tables 6 and Table 7). So, banning of copper is not desirable in case of white grapefruit. However, adding together the net revenue change for red and white grapefruit shows an increase for all 10 years of the estimated period with low cost alternative (Table 5) and an increase for eight years out of 10 with high cost alternative (Table 6). Using the base year yield per acre data for all grapefruit as 404 boxes, per box cost impact of above cost involvements can be calculated and thus, the on-tree prices received by producers will also be affected. Since the per box cost involvement will be about \$0.40 and \$ 1.03, the expected on-tree prices received by producers will also be less by the same amount.

Sensitivity Analysis

Since the study is examining the impacts of not using copper in grapefruit production, it is worthwhile to look at the parameters that are sensitive to copper (Table 1A). Thus, sensitivity analysis is conducted on the yield and pack-out parameters. The alternative model without copper has been run with 5 percent and 9 percent decreases in yield and the results are compared with those of the base model with copper. The alternative model is run considering the combined impact of melanose and greasy spot on pack-out (35 percent for melanose and 15 percent for greasy spot) and then, it is re-run with 5 percent lower and 5 percent higher combined impacts on pack-out (Table 8) and the results are compared with those of the base model in order to look at the robustness of the findings. The combined pack-out impact is calculated using a formula as equal to the base pack-out multiplied by (1 – melanose impact) times (1 – greasy spot impact). For example, since the base model uses pack-out rates as 0.60 for domestic red and white as well as for Canada red grapefruit, 0.58 for Europe red grapefruit and 0.39 for Japan white grapefruit, the pack-out for domestic red and white in the alternative model is equal to 0.60 (1-0.35)* (1-0.15). The same procedure is followed to get the pack-out rates with 5 percent lower (30 percent for melanose and 10 percent for greasy spot) and 5 percent higher (40 percent for melanose and

20 percent for greasy spot) pack-out impacts. As the impacts on producers and consumers are the main concerns in the model, sensitivity is also undertaken with especial attention to on-tree prices, revenue and FOB prices.

For yield sensitivity, it is found that instead of a 171 percent increase in average on-tree price of red grapefruit over the estimated period in the alternative model (with a 7 percent negative yield impact), the increase becomes 165 percent with 5 percent negative yield impact and 175 percent with 9 percent negative yield impact. In case of white grapefruit, the increase is 73 percent with 5 percent negative yield impact and 64 percent with 9 percent negative yield impact instead of a 68 percent increase in the alternative model. It is observable here that the ultimate result of the model remains the same in the sense that with the ban of copper, on-tree prices of both red and white grapefruit increase. The same is true for pack-out sensitivity also.

Sensitivity results on revenue shows that while the increase in total revenue on the average over the period was 152.49 percent for red grapefruit and 3.59 percent for white grapefruit in the alternative model, it is 153.10 percent with 5 percent negative yield impact and 152.26 percent with 9 percent negative yield impact for red grapefruit, and 2.35 percent with 5 percent negative yield impact and 3.94 percent with 9 percent negative yield impact for white grapefruit. Total revenue increases for both types of grapefruit even though the increase is very small in case of white grapefruit. The same tendency is found for pack-out sensitivity in case of red grapefruit; but for white grapefruit, revenue increases by 11.45 percent with 5 percent lower pack-out impact whereas it decreases by 20.117 percent with 5 percent higher pack-out impact.

The alternative model with 35 percent for melanose and 15 percent for greasy spot pack-out impact (negative) shows that fresh utilization decreases by 45.53 percent for red grapefruit and by 49.59 percent for white grapefruit. Pack-out sensitivity results show that for red grapefruit the decrease is 37.52 percent with 5 percent lower and 52.25 percent with 5 percent higher negative pack-out impacts. For white grapefruit the decrease is 36.22 percent with 5 percent lower and 67.68 percent with 5 percent higher negative pack-out impacts. Hence, the alternative model and the sensitivity analysis thereon suggest that with a ban on copper, fresh utilization of both types of grapefruit decreases.

For processed utilization, the alternative model shows that there is an increase of 32.93 percent for red grapefruit while there is a decrease of 33.84 percent for white grapefruit. Pack-out sensitivity results show that the increase in processed utilization is 25.98 percent with 5 percent lower and 40.85 percent with 5 percent higher pack-out impacts for red grapefruit while the decrease in processed utilization for white grapefruit is 25.79 percent and 43.00 percent respectively. Here, the ultimate result of banning copper on processed utilization of grapefruit remains the same with pack-out sensitivity as undertaken.

With yield and pack-out sensitivity the model provides almost the same results on FOB prices which means that both export and domestic prices increase. So, sensitivity analysis does not contradict the results of the alternative model.

Conclusions

When copper is banned from grapefruit production, on-tree prices increase leading to an increase in grower revenue, fresh marketing decreases, FOB packinghouse prices for domestic and international markets increase whereby the consumer prices increase at the same time. Even though the cost of production increases, net revenue to grove owners using no copper is greater than when copper is used.

The main conclusion of the study is that a ban on copper in grapefruit production has a negative impact on consumers in terms of higher prices and lower grapefruit consumption, but a positive impact for producers in terms of the overall increase in net revenue.

Implications

The net social implication is not clear. There would be gainers and loosers if copper were withdrawn from grapefruit production. Producers gain net revenue, but consumers pay more for grapefruit. Policy makers need to consider the increase in producer's gain as opposed to the decrease in consumer's loss as well as other environmental consequences, if any, before taking decision.

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Table 1A. The Impacts of Alternatives to Copper.

Alternatives	To Control	Yield Impact	Packout Impact	Cost Impact/acre (*in dollars*)
Benomyl (50%)	Scab	0	0	+ 20.19
Ferbam (50%)	Scab	0	0	+ 277.15
Benomyl (100%)	Melanose	0	- 35%	+ 120.27
Petroleum (100%)	Greasy Spot	- 7%	- 15%	+ 20.34

** + (Positive sign) means increase in cost and - (negative sign) means decrease in yield/pack-out.

Source: NAPIAP, USDA. NAPIAP Report No. 1-CA-99

Table 1. Estimated Production, Utilization, On-tree Price, Total trees and Revenue for Red Grapefruit with and without Copper, 2001-02 through 2012-13.

Model With Copper

Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2001-02	27800	27800	2.363	6973.8	65687.08
2002-03	28999.094	28999.094	2.451	6887.51	71071.72
2003-04	28513.252	28513.252	2.626	6801.25	74875.39
2004-05	27985.763	27985.763	2.81	6722.6	78644.5
2005-06	27501.233	27501.233	2.976	6654.27	81840.2
2006-07	27041.944	27041.944	3.134	6600.78	84761.69
2007-08	26614.575	26614.575	3.285	6564.9	87429.14
2008-09	26205.802	26205.802	3.432	6542.33	89942.69
2009-10	25848.228	25848.228	3.566	6535.37	92175.91
2010-11	25550.628	25550.628	3.684	6544.79	94136.26
2011-12	25319.018	25319.018	3.784	6569.14	95801.86
2012-13	25150.519	25150.519	3.862	6607.73	97142.09

Table 1 (continues…)

Model With Out Copper

Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2001-02	27800	22434.801	2.73	6973.8	61250.35
2002-03	26964.981	26400.315	2.415	6893.22	63747.89
2003-04	26513.863	26420.34	2.432	6815.39	64267.17
2004-05	26027.821	26027.821	2.528	6743.67	65790.67
2005-06	25589.874	25589.874	2.627	6671.21	67229.08
2006-07	25177.391	25177.391	2.723	6602.32	68545.58
2007-08	24788.123	24788.123	2.815	6541.2	69778.89
2008-09	24398.27	24398.27	2.91	6484.94	70997.65
2009-10	24034.709	24034.709	3.002	6436.99	72159.96
2010-11	23705.937	23705.937	3.091	6399.17	73272.52
2011-12	23417.171	23417.171	3.173	6371.14	74314.25
2012-13	23163.924	23163.924	3.248	6353.39	75241.63

Table 2. Estimated Production, Utilization, On-tree Price, Total trees and Revenue for White Grapefruit with and without Copper, 2001-02 through 2012-13.

Model With Copper

Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2001-02	18900	18900	1.835	4320.8	34673.35
2002-03	21188.084	16928.737	1.615	4261.47	27334.17
2003-04	20965.508	16885.817	1.659	4205.65	28012.25
2004-05	20802.608	16872.887	1.701	4150.58	28696.9
2005-06	20649.502	16880.792	1.736	4094.02	29299.73
2006-07	20468.644	16880.915	1.77	4036.6	29873.55
2007-08	20258.635	16865.399	1.803	3980.98	30413.91
2008-09	20010.076	16834.062	1.838	3927.92	30933.34
2009-10	19731.625	16779.126	1.871	3878.05	31391.83
2010-11	19417.544	16696.525	1.903	3830.11	31775.02
2011-12	19074.017	16591.858	1.933	3783.81	32068.92
2012-13	18767.269	16481.71	1.958	3739.97	32272.8

Model With Out Copper

Year	Production (*1000 boxes*)	Utilization (*1000 boxes*)	On-tree Price (*$/ box*)	Total trees (*1000 boxes*)	Revenue (*1000 dollars*)
2001-02	18900	18900	1.145	4320.8	21637.51
2002-03	19710.928	16142.564	2.033	4257.98	32820.1
2003-04	19502.375	16104.212	2.057	4198.11	33122.24
2004-05	19346.286	16190.91	2.107	4140.56	34109.05
2005-06	19196.526	16302.499	2.152	4088.31	35089.28
2006-07	19019.32	16402.598	2.197	4040.45	36034.45
2007-08	18822.131	16488.783	2.242	3998.55	36962.96
2008-09	18598.848	16567.756	2.289	3962.5	37921.57
2009-10	18360.758	16628.423	2.337	3932.27	38867.93
2010-11	18103.286	16665.946	2.388	3906.08	39791.57
2011-12	17831.263	16682.244	2.437	3883.28	40662.76
2012-13	17605.27	16688.791	2.483	3864.48	41445.78

Table 3. Estimated Fresh and Processed Quantity and Price for Red Grapefruit with and without Copper, 2001-02 through 2012-13.

Model With Copper

Year	**Fresh Qty.** (*1000 boxes*)	**Price (Fresh)** (*$/ box*)	**Processed Qty.** (*1000 boxes*)	**Price (Processed)** (*$/box*)
2001-02	12771.303	4.684	15028.697	0.39
2002-03	12643.966	4.89	16355.128	0.565
2003-04	12423.314	5.162	16089.939	0.668
2004-05	12183.799	5.459	15801.965	0.768
2005-06	11963.82	5.732	15537.413	0.853
2006-07	11755.29	5.992	15286.654	0.937
2007-08	11561.229	6.234	15053.347	1.02
2008-09	11375.586	6.466	14830.217	1.105
2009-10	11213.152	6.67	14635.076	1.188
2010-11	11077.906	6.839	14472.722	1.27
2011-12	10972.587	6.97	14346.431	1.347
2012-13	10895.914	7.065	14254.605	1.414

(Without Copper)

Model With Out Copper

Year	**Fresh Qty.** (*1000 boxes*)	**Price (Fresh)** (*$/ box*)	**Processed Qty.** (*1000 boxes*)	**Price (Processed)** (*$/box*)
2001-02	5157.053	15.057	17277.748	-0.949
2002-03	6121.541	14.582	20278.774	-1.258
2003-04	6160.136	14.516	20260.204	-1.242
2004-05	6068.245	14.668	19959.576	-1.163
2005-06	5958.297	14.852	19631.577	-1.083
2006-07	5854.734	15.028	19322.657	-1.006
2007-08	5756.985	15.195	19031.137	-0.93
2008-09	5659.077	15.364	18739.193	-0.851
2009-10	5567.75	15.524	18466.96	-0.773
2010-11	5485.132	15.67	18220.805	-0.696
2011-12	5412.539	15.798	18004.631	-0.622
2012-13	5348.863	15.912	17815.061	-0.554

Table 4. Estimated Fresh and Processed Quantity and Price for White Grapefruit with and without Copper, 2001-02 through 2012-13.

Model With Copper

Year	**Fresh Qty.** (*1000 boxes*)	**Price (Fresh)** (*$/ box*)	**Processed Qty.** (*1000 boxes*)	**Price (Processed)** (*$/box*)
2001-02	3046.56	7.079	15853.44	0.827
2002-03	4959.002	3.756	11969.735	0.728
2003-04	4977.064	3.649	11908.753	0.827
2004-05	4994.703	3.545	11878.184	0.925
2005-06	5009.749	3.456	11871.044	1.01
2006-07	5024.441	3.369	11856.473	1.092
2007-08	5039.028	3.282	11826.371	1.173
2008-09	5053.945	3.194	11780.117	1.255
2009-10	5068.605	3.108	11710.521	1.336
2010-11	5082.965	3.023	11613.56	1.413
2011-12	5096.504	2.943	11495.354	1.485
2012-13	5108.344	2.873	11373.366	1.547

(Without Copper)

Model With Out Copper

Year	**Fresh Qty.** (*1000 boxes*)	**Price (Fresh)** (*$/ box*)	**Processed Qty.** (*1000 boxes*)	**Price (Processed)** (*$/box*)
2001-02	1657.812	18.603	17242.188	-0.534
2002-03	2600.648	18.343	13541.916	-1.099
2003-04	2610.528	18.278	13493.684	-1.081
2004-05	2647.662	18.032	13543.248	-1.007
2005-06	2685.226	17.786	13617.273	-0.93
2006-07	2721.472	17.548	13681.126	-0.857
2007-08	2757.114	17.316	13731.67	-0.785
2008-09	2794.081	17.076	13773.676	-0.711
2009-10	2830.804	16.839	13797.619	-0.638
2010-11	2867.017	16.606	13798.929	-0.567
2011-12	2901.711	16.383	13780.533	-0.499
2012-13	2933.48	16.18	13755.311	-0.438

Do we have to include this too?

Table 5. Revenue Impact on Producers with Lower Cost Assumption for Red and White Grapefruit (Fresh and Processed), 1998-9 through 2007-8

(in 1000 dollars)

Year	Red Base	Red Adjusted	Red Change	White Base	White Adjusted	White Change
1998-9	$ 87174.69	$ 115013.35	$ 27838.66	$49718.98	$ 36626.96	$-13092.02
1999-0	31674.80	117901.73	86226.93	36927.57	34501.50	-2426.07
2000-1	31727.04	118193.85	86466.81	36868.74	34518.48	-2350.25
2001-2	31735.74	118159.02	86423.29	36830.70	34636.44	-2194.26
2002-3	31700.64	118058.13	86357.49	36814.96	34684.93	-2130.03
2003-4	33707.95	117808.14	84100.19	36847.49	34823.99	-2023.49
2004-5	45848.21	117546.25	71698.05	37452.40	34919.93	-2532.47
2005-6	58961.15	117305.08	58343.93	38523.45	34979.74	-3543.71
2006-7	72098.44	117091.14	44992.71	41080.29	35015.00	-6065.29
2007-8	85113.26	116916.53	31803.27	45361.38	35002.24	-10359.14

Table 6. Revenue Impact on Producers with Higher Cost Assumption for Red and White Grapefruit (Fresh and Processed), 1998-9 through 2007-8

(in 1000 dollars)

Year	Red Base	Red Adjusted	Red Change	White Base	White Adjusted	White Change
1998-9	$ 87174.69	$ 96998.02	$ 9823.34	$ 49718.98	$ 25924.79	$ -23794.19
1999-0	31674.80	100320.66	68645.86	36927.57	24175.69	-12751.88
2000-1	31727.04	100873.95	69146.91	36868.74	24552.68	-12316.06
2001-2	31735.74	100764.28	69028.55	36830.70	24906.83	-11923.88
2002-3	31700.64	100452.43	68751.79	36814.96	25099.02	-11715.93
2003-4	33707.95	99923.82	66215.87	36847.49	25324.26	-11523.22
2004-5	45848.21	99343.93	53495.72	37452.40	25472.91	-11979.49
2005-6	58961.15	98765.42	39804.28	38523.45	25572.16	-12951.30
2006-7	72098.44	98201.72	26103.28	41080.29	25642.85	-15437.44
2007-8	85113.26	97670.93	12557.67	45361.38	25661.50	-19699.88