Ex ante Economics of Exotic Disease Policy: Citrus Canker in California

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1. Introduction

This paper investigates the economic effects of an invasion of citrus canker in California. We consider the costs and benefits of eradication under alternatives including the size of the infestation, whether it occurs in commercial groves or in urban areas, and various economic and market conditions. The impacts of various eradication scenarios are compared to the alternative of allowing the disease to become established again under various conditions, including the potential for quarantine. We do not consider here the likelihood of an infestation or the specifics of exclusion policies. Rather we focus on economic considerations of eradication versus establishment.

2. A background on the disease, its prevalence, and spread

Citrus canker is a bacterial disease of most commercial *Citrus* species and cultivars grown around the world, as well as some citrus relatives (Civerolo, 1984; Goto 1992a; Goto, Schubert 1992b; and Miller, 1999). Citrus canker is established primarily in tropical and subtropical areas where high temperatures and rainfall occur at the same time of the year (Civerolo, 1984; Civerolo, 1994; Stall and Civerolo, 1993). However, it has also established in southwest Asia (Iran, Iraq, Oman, Saudi Arabia, the United Arab Emirates and Yemen) in recent years (Commonwealth Mycological Institute, 1996). The disease is caused by *Xanthomonas campestris* (*=axonopodis*) pv. **citri** (*Xcc)* (Goto, 1992a: Goto, 1992b; Stall and Civerolo, 1991; Stall and Civerolo, 1993; Vauterin, et al, 1995; Young, et al, 1996). However, distinct pathotypes of *Xcc* are associated with different forms of the disease (Civerolo, 1984; Stall, et al, 1982; Verniere, et al, 1998). Citrus canker probably originated in Southeast Asia or India, and now occurs in more than 30 countries.

This pathogen causes erumpent lesions on leaves, stems, twigs and fruit (Civerolo, et al, 1984 Goto, 1992a; 1992b; Schubert and Miller, 1999). Severe infections can result in defoliation, unsightly blemished fruit, premature fruit drop, twig dieback and general tree decline (Goto, 1992a; Goto, 1992b).

Asiatic citrus canker is the most economically important and most widespread form of the disease globally (Goto, 1992a; Goto, 1992b). Considerable national and international regulatory efforts are designed to prevent spread of the pathogen to, and disease establishment in, citrus growing-regions around the world where the disease is not endemic, but where environmental conditions are conducive to disease development (Goto, 1992b). Other forms of the disease are rarely found in nature (Civerolo, 1984; Verniere, et al, 1998); however, all strains of the *Xcc* associated with different forms of the disease are subject to the same international phytosanitary regulations.

Despite these regulations, infestations in the U.S. occurred in the Gulf States around 1910, and in Florida in 1986, 1995, and from 1997 to the present (Gottwald, et al, 1997; Schubert and Miller, 1999). The 1910 infestation was eradicated over a period of several years with significant economic losses to producers due to lost plant and crop values, and to regulatory agencies due to eradication costs. The last detection of the 1986 outbreak was in 1992. However, the 1986 and 1997 infestations were associated with closely related strains of the pathogen. This suggests that holdover infections from the 1986-92 infestation went undetected. The 1986 and 1995 infestations were caused by genetically distinct strains of *Xcc*. By December 1999 the disease had spread to over 400 sq. miles of urban areas and into commercial lime groves. An eradication program is currently underway to eliminate Citrus canker infestations in Florida (Gottwald, et al, 1997; Schubert and Miller, 1997. In January 2000 approximately 600 acres of lime groves were burned as part of the Florida citrus canker eradication program.

California has never experienced an infestation of citrus canker. Citrus grown in California is protected under an USDA external quarantine against the importation of citrus fruit, stock, and other fresh or dried products from countries known to have citrus canker. It is also protected by an USDA internal quarantine around regions within the U.S. known to have citrus canker. In addition, California maintains its own restrictions against the importation of citrus and citrus nursery stock.

All above ground tissues of citrus are susceptible to infection by *Xcc* (Civerolo, 1984; Goto 1992a; Goto, 1992b; Schubert and Miller, 1999; Stall and Civerolo, 1993). Infection generally occurs through natural openings (stomates, lenticels) and wounds. On leaves, minute, blister-like lesions appear on the lower surface initially about 7-10 days after infection occurs under optimum conditions. Over time, these become tan or brown with a watersoaked margin, and surrounded by a chlorotic halo. The lesions become distinctly raised and have a corky appearance. At this stage, lesions are usually visible on both leaf surfaces. The lesions become erumpent and the centers become crater-like. The centers of the lesions may fall out creating a shot-hole effect. Severe leaf infection may result in defoliation. Lesions on twigs and fruit are generally similar to those on leaves. Blemished fruit and premature fruit drop are major impacts of the disease if trees are left untreated.

Several pathotypes of *Xcc* are characterized by their natural host range (Civerolo, 1984; Stall And Civerolo, 1993). The most virulent pathotype, *Xcc*-A, is associated with the Asiatic form of Citrus canker (Civerolo, 1984; Goto, 1992a; Goto, 1992b; Stall and Civerolo, 1993). While the host range of *Xcc*-A is broader than that of the other pathotypes, phenotypically distinct strains of *Xcc*-A (designated *Xcc*-A*) with pathogenicity limited to Mexican lime (*Citrus* *aurantifolia*) in India and Southwest Asia have recently been described (Verniere, et al, 1998). Pathotype *Xcc*-B is associated with cancrosis B (CBCD-B) in a few countries in South America (Argentina, Uruguay, Paraguay) and has a restricted natural host range. Lemon (*C. limon*) is the most susceptible species, while sweet orange (*C. sinensis*) is little affected under natural conditions. Pathotype *Xcc*-C is associated with Mexican lime cancrosis (CBCD-C) in Brazil. Other pathogenic variants of *Xcc* may exist.

Citrus canker occurs most frequently and severely in citrus-growing areas characterized by warm, humid weather (Goto, 1992a; Goto, 1992b; Schubert and Miller, 1997; Stall and Civerolo, 1993). However, environmental conditions in many, if not all, citrus-growing areas are likely to be conducive to infection and disease development (Stall and Civerolo, 1993). The *Xcc* pathogen overwinters in lesions following infection in autumn on diseased leaves, twigs and stems. In the spring, bacteria ooze out of old lesions when free water is available. These bacteria cause new infections on young leaves in the spring. Lesions on leaves are the primary sources of inoculum for fruit infection in the summer (Goto, 1992a). Figure 1 previdess a scheamitic of the disease cycle.

The extent of infection and severity of disease development depend on the specific *Citrus* species and cultivar, environmental conditions and *Xcc* pathotype (Civerolo, 1984; Goto, 1992b; Gottwald, et al, 1997; Pruvost, et al, 1997). All young, developing, aboveground parts of susceptible citrus hosts can be infected (young leaves, twigs, thorns, branches and fruit). Infection occurs primarily through stomates, other natural openings or wounds. Resistance of leaves and fruit to infection increases with maturity (Goto, 1992a; Goto, 1992b; Stall and Civerolo, 1993).

Xcc survives in diseased host plant tissues parasitically, on host and nonhost plants and to a limited extent in association with plant tissue debris in the soil (Goto,1992a; Goto, 1992b) . *Xcc* can survive for long periods in infected bark tissue of trunks, low scaffold limbs, and lateral branches.

Long-distance dissemination of *Xcc* occurs primarily via the movement of infected planting stock (e.g. rootstock seedlings, budded nursery trees) and propagating material (e.g. budwood) (Civerolo, 1984; Goto, 1992b; Gottwald, et al 1997; Pruvost, et al, 1997; Schubert and Miller, 1999; Stall and Civerolo, 1993). Infected fresh fruit with lesions is a potential means of long-distance spread of *Xcc*; however, there is no authenticated record that this is epidemiologically significant with respect to initiation of new infections. There is no record of transmission of *Xcc* via seed. Infested personnel, clothing, tools, equipment, boxes, and other items associated with harvesting and postharvest handling of fruits are potential means of *Xcc* dissemination over short to long distances, at least for a limited time. Long distance dispersal of *Xcc* by animals, birds, and insects has not been conclusively demonstrated.

Short distance spread of *Xcc* within trees, and from tree to tree, occurs primarily via wind-driven rain, especially during storms, typhoons, and hurricanes (Civerolo, 1984; Goto, 1992b; Gottwald, et al, 1997; Pruvost, et al, 1997). Strong winds that cause injuries on leaves, twigs, and fruit, and rainstorms (as well as thunderstorms, tornadoes, tropical storms and hurricanes) that disperse the pathogen, facilitate infection. *Xcc* infection can be facilitated by feeding activities of the citrus leaf miner.

Violations of current quarantine regulations excluding citrus fruit, citrus stock and other citrus products from infested regions are a potential source for the introduction of citrus canker into California. The movement of goods often accompanies the movement of people, despite quarantine regulations against some of those goods. Either people are unaware of the restrictions, are unaware of the reasons for the restrictions, or are indifferent to them. Under those circumstances, citrus canker may be accidentally introduced as people bring in fruit or budwood from infested areas.

Citrus canker may also be introduced by people deliberately violating quarantines through commercial smuggling activities. Citrus canker has been identified on dried kaffir lime leaves smuggled into California. Dried kaffir lime leaves are a basic seasoning ingredient used in Thai and other Southeast Asian cuisine. The dried leaves do not contain any active bacteria that can lead to the introduction of citrus canker. However, concerns exist that, in response to the demand for ethnic food products, budwood could be smuggled into the country. In recognition of this potential problem Lincove, an organization that carries out research on improving citrus stock, grew and distributed about 300 kaffir lime trees to commercial citrus producers from clean citrus stock (Stutsman, 1999).

3. Intervention policy and economic background

Citrus canker management is based on integrated systems of regulatory measures, disease forecasting, planting resistant or tolerant types of citrus, cultural practices, chemical sprays, and biological control (Civerolo, 1984; Goto, 1992b; Stall and Civerolo, 1993). Intervention strategies include exclusion, eradication and treatment should it become established.

Exclusion regulatory measures include state, national, and international quarantines. National and state quarantines ban the importation of citrus stock from other regions. The importation of fresh fruit, peel and leaves from eastern and south-eastern Asia (including India, Myanmar, Sri Lanka, Thailand, Vietnam and China), the Malayan Archepelago, Philippine Islands, Oceania (except Australia and Tasmania), Japan, Taiwan, Mauritius Seychelles, Paraguay, Argentina and Brazil is banned due to the presence of citrus canker in those countries.

Should the exclusion regulatory measures fail, occurrence of Citrus canker in California is likely to initiate increased regulatory activities, including (but not necessarily limited to) implementation of an Action Plan to delimit, contain, suppress, and eradicate any infestation by state and federal regulatory agencies.

Should citrus canker enter California, public regulatory agencies would be responsible for its eradication, if feasible, as homeowners and individual producers would not have strong incentives to voluntarily remove trees. Failure to remove the disease would result in negative spill-over effects on other groups as citrus canker would spread to other residences and commercial operations. Eventually the disease would spread sufficiently so that commercial production and market prices are affected. The costs and benefits to other groups do not usually factor fully into private decisions, but are of concern to government regulatory agencies and other groups. This is why state and federal regulatory agencies are responsible for eradication programs.

Should the eradication measures fail and citrus canker become established, the cultural and marketing strategies available to tree owners would include the use of pathogen- or disease-free nursery planting stock and propagating material; and pre- and postharvest chemical treatments (e.g. copper- containing sprays; sodium hypochlorite). In that case, regulatory agencies would no longer be responsible for mitigating costs associated with the disease.

Parties affected by citrus canker include homeowners; citrus nurserymen, producers, exporters, and fruit processors; wholesale and retail nursery outlets that include citrus, citrus relatives and other rutaceous plants; users of citrus, citrus relatives and other rutaceous plants that might be *Xcc* hosts for landscape and other horticultural purposes; domestic and foreign consumers of fresh citrus fruit and citrus products; and tax payers.

Homeowners are potentially affected by the possibility of tree removal during an eradication program, or decreased production if citrus canker become established. Many homeowners grow citrus in their backyards. In a plant survey of 3,000 backyards in Northern and Southern California, nearly 3,000 citrus trees were counted (CDFA, 1994). The predominate type of citrus planted in backyards is lemon, followed by fresh oranges.

The California citrus industry is one of the state's largest agricultural industries. The combined crop value of oranges, lemons, and grapefruit in the 1997-98 season was approximately $900 million. The Southern San Joaquin counties of Tulare, Kern and Fresno account for 64 percent of all citrus production in the state. Other counties with significant citrus production include Ventura (20 percent), Riverside (6 percent) and San Diego (5 percent) (CDFA, 1999). Oranges, lemons, and grapefruit, the three major crops that constitute the California citrus industry, are augmented by limes, tangerines, and numerous hybrid citrus fruits. In addition to citrus producers, the citrus industry is interrelated with many other agribusiness industries including producers and suppliers of inputs to citrus production, packinghouses, and processors.

Consumption of California citrus has grown steadily during the past decade and growth trends are projected to continue. During the past 9 years the United States per/capita citrus consumption (fresh fruit and juice) has increased by 20 percent, while the population has increased by 7 percent. Similarly, foreign consumption of California citrus products is increasing. California's citrus exports to foreign countries were approximately $411 million dollars in 1998. Recently, protocols to export California citrus to China were approved, and shipments to China began March 24, 2000 (CDFA, 2000).

Taxpayers, and state and federal regulatory agencies would also be affected. State and federal agencies are entrusted with protecting plant health from exotic pests and diseases. Most costs associated with inspecting, surveying, monitoring, and eradicating exotic pests and diseases are incurred by taxpayers who fund these agencies.

Should citrus canker enter California, the effect on producers and consumers depend upon the U.S. and California government regulatory intervention strategy pursued, policy response of importing regions, time period considered in the assessment, and consumer and producer response to price changes. Government intervention strategies include eradication or allowing the disease to become established. Importing regions may continue to accept California citrus with no restrictions, accept it provided pre- and post-harvest treatment conditions are met, or impose quarantines. Consumer and producer responses depend in part on the time frame considered for the analysis. In the short run supply adjustments are limited; in the long run acreage adjusts and the industry fully reallocates resources.

The effects on producers and consumers of an outbreak of citrus canker that is subsequently eradicated can be shown graphically. In the short-run the removal of acres due to eradication would cause the supply curve, S, to shift up to S' (Figure 2).

Market supply would decrease from Q to Q'sr and price would rise to P'sr. Over time producers would response to the higher prices by planting new groves. Production would gradually increase as those trees start bearing fruit, market supply would increase and prices would start to fall. In the long run the original equilibrium conditions between market supply and price would be restored.

If citrus canker enters and is not eradicated it would gradually spread and become established. Production costs would increase, and the industry supply curve would gradually shift up from S to S' (Figure 3). The short-run supply curve is steeper than the long-run curve to reflect that in the short-run producers find it costly to adjust to changes in market prices.

If quarantines are imposed by importing regions then the demand curve would shift from D to D'. Note that the vertical shift up of the supply curve would be the same in the short run as in the long run. This would also be true for demand. The shift in demand would be the same for each time horizon.

In the short-run producers cannot easily move acreage out of production and into the cultivation of other crops. While production would decrease somewhat to Q'sr, the remaining production would be shipped into a smaller, non-quarantined, market, and prices would fall to P'sr. In the long-run groves would be removed. The subsequent decline in quantity supplied, to Q'lr, would cause prices to increase to P'lr.

4. Alternative policy scenarios

As noted above citrus canker has never been found in California. Should it enter California, the two main policy responses would be to eradicate it, or to let it become established. The costs and benefits of each policy response are influenced by additional domestic and international policy choices.

Federal or state governments may choose to eradicate without any compensation to homeowners or producers, or offer some type of partial to full compensation. The policy in the Florida eradication program is that no compensation would be paid to homeowners. An alternative would be to compensate homeowners either at the replacement value, or at the appraised value, of a citrus tree.

Until recently producers have not received any compensation from state or federal regulatory agencies. During 1999, however, a pilot program was started offering producers the opportunity to purchase subsidized federal crop insurance for citrus canker. Producers who purchase crop insurance for citrus canker may submit claims if trees are destroyed during an eradication campaign. Producers would be compensated based on the actuarial value of a citrus tree. An alternative approach would be to compensate producers in the amount equal to the investment value of their grove.

International regulations allow foreign governments to impose pre- and post-harvest restrictions and quarantines against California citrus and citrus stock should citrus canker be identified. Importing regions or nations may impose restrictions on California citrus and citrus products if an outbreak of an exotic pest occurred that they did not have. Internal quarantine regulations may also result in a ban on the movement of California citrus products to other citrus producing states and U.S. territories.

One issue that has arisen in the Florida urban eradication program is how far the tree removal boundary around the infested tree should be extended. The more the boundary is extended, the higher is the probability that the disease would be eradicated. However, eradication costs would also be higher. Originally, the boundaries in the Florida urban eradication program were set at 125 feet around any tree found to be infested. Research later showed that the eradication boundary needed to be 1,900 feet around an infested tree in order to have a 95 percent chance of successfully eradicating citrus canker. For a 99 percent chance, the zone needs to be extended to a 3,000 feet perimeter. This difference in area eradicated has potentially large cost consequences depending on the size of the eradication program.

The above policy issues were used to develop the following scenarios:

1) Urban Eradication Program
    a) Eradication with a 125 feet buffer zone.
    b) Eradication with a 1,900 feet buffer zone.

    - c) Eradication with a 3,000 feet buffer zone.
    - d) No compensation to homeowners.
    - e) Homeowners compensated by issuing a voucher that can be used to purchase a replacement plant.
    - f) Homeowners compensated though payments based on the appraised value of the citrus tree removed.

2) Commercial Grove Eradication Program
    - a) No compensation to producers.
    - b) Federal crop insurance is available.
    - c) Producers compensated based on the investment value of a grove.

3) Establishment
    - a) Internal and foreign quarantines imposed.
    - b) No quarantines imposed.

Notice that a large number of potential scenarios are created by this set of options. With three buffer zones and three homeowner compensation policies there are nine urban eradication scenarios. The commercial eradication program adds three more scenarios and establishment policy two. In addition, the effects on consumers and producers are examined under three different consumer and producer response scenarios to changes in prices. In total there are 21 scenarios. The 21 scenarios are the nine urban eradication ones, three commercial compensation, three consumer and producer response scenarios to a commercial eradication program, and six establishment scenarios (the two quarantine scenarios times three consumer and producer response scenarios).

5. Analysis of economic effects of alternative policies

5.1 Government outlay costs

The costs of eradicating citrus canker from an urban area include government outlays and private costs to homeowners. First, the cost to estimate the smallest possible infestation in an urban area is calculated. The smallest possible infestation is one tree. We consider the minimum costs for three eradication zone choices (125 feet, 1900 feet, 3000 feet) and the three different compensation policies (none, voucher, appraised value).

Government outlays are calculated as the cost per tree for removal, disposal and compensation, times the number of trees within each eradication zone, plus inspection and monitoring costs. The price to cut down and dispose of a citrus tree in an urban area was obtained from the Florida Department of Agriculture and Consumer Services (FDACS) (Timothy Schubert, personal communication, Leon Haab personal communication, and Doug Hadlock, personal communication). As of December 1999 tree removal and disposal costs were \$58.00 a tree. This price reflects a steady increase over time from the start of the eradication program. For our calculations, the dollar amount is rounded up to \$60.00 per tree.

The number of trees per square mile was calculated as

$$\frac{trees}{square\ mile} = \frac{trees}{backyard} * \frac{backyards}{square\ mile}$$

where the number of trees per backyard is from backyard plant surveys competed in California during a Mediterranean fruit fly urban eradication program (CDFA, 1994) and the backyards per square mile is calculated by dividing the number of single homes and duplexes in urban areas by the number of urban square miles (USDC, 1991).

Additional costs would be incurred by the government if compensation is paid to homeowners for their losses. If regulatory agencies opt to compensate a homeowner for the loss of a tree through issuing a voucher that could be redeemed at a nursery, the cost, based on a survey of nurseries in California, would range from $15.99 to $23.99. We use a price of $20.00 per tree. If compensation is paid according to the appraised value of a live mature tree in a home setting, then the cost is estimated to be $400 per tree. This cost was estimated using the tree appraisal techniques developed by the International Society of Arboriculture (ISA, 1992).

In the Florida citrus canker eradication program surveillance and monitoring activities are completed six times within the eradication zone, two times within five miles of the zone and once within 10 miles of the zone (Schubert, 1999). The costs for regulatory agencies to inspect, survey and monitor an urban eradication program is set at $90,000 per square mile within the eradication zone. This figure is calculated as the level of USDA and FDACS funding specifically for citrus canker removal, less tree removal costs, then divided by the estimated size of the infestation in Florida as of December 1999.

The analysis of the urban eradication costs is based on a constant rate of spread from the original infestation point. Costs are calculated as the disease spreads 2,500 feet, then 5,000 feet, then 7,500 feet, etc., out from the origin of the infestation. For analytical purposes we assume that the infestation spreads outward in a circle around the original infestation point.

Not included in this analysis are the effects on consumers of buying citrus in stores instead of picking citrus off of backyard trees. We have no data on home consumption of citrus fruit and we assume that this is a small share of total market consumption. We also exclude the costs of homeowner resistance to the eradication of backyard trees.   Homeowner resistance could result in extra public expenditures for education and outreach in order to ensure public support and compliance, and thereby raise the total amount of government outlays to eradicate citrus canker.

The costs to remove publicly owned citrus trees are also not included in these calculations. Based on street tree inventories from seven cities in California, most cities do not plant more than a handful of citrus trees. On average there were only 1.5 citrus trees every square mile and the average expected cost of eradication is not significantly influenced by the presence of publicly owned citrus trees. However, if citrus canker is introduced into a city with many citrus street trees, local costs would increase substantially.

The costs of eradicating citrus canker from commercial groves include government outlays associated with the commercial eradication program, and private costs to citrus consumers and producers from potential changes in market supplies and prices. Calculating the size of the infestation based as a constant spread from the initial point is not practical. Therefore, the size of the infestation was fixed at different acres and costs estimated for that acreage. Commercial grove eradication costs include bulldozing the grove, disposal (either through burning or tree removal), and inspection and monitoring costs. Compensation choices include no compensation, subsidized crop insurance, and indemnification in an amount equal to the investment value of a citrus grove.

Costs per acre to bulldoze and burn a citrus grove were obtained from the Florida Department of Agriculture and Consumer Services. In 1999 these costs were between $250 and $350 an acre. We use $300 an acre in this study.

The first compensation policy is to pay nothing and crop losses then accrue to producers. The next policy is to offer producers subsidized federal crop insurance. The Florida Fruit Tree Pilot Crop Insurance Provisions provided the data used to estimate this cost (USDA, 1999a). Based on the Florida data, the actuarial value of one citrus tree is $26. Based on crop budgets developed by the University of California Cooperative Extension service, there are typically 110 trees per acre for oranges and grapefruit, and 136 trees per acre for lemons (O'Connell, et al., 1999; Takele, et al., 1997a; Takele, et al., 1997b). Full coverage was $2,860 per acres of oranges or grapefruit $3,536 per acre of lemons. Because we do not know which groves would be infested, a weighted average was calculated for an average value of $3,000. The premium is 2.8 percent of the full coverage amount or $84. Compensation to producers is then $3,000 less $84 or $2,916 per acre.

Investment values reflect the price to purchase land on which a grove is planted. The value of the grove itself was calculated as the average price paid for the land on which the citrus grove was planted less the average price paid for open land (CALASFMRA, 1999). These numbers were then adjusted based on interviews with farmland appraisers located in the counties were citrus is grown. The average investment value is estimated as $5,300 an acre. Note that this number is far higher than even the full coverage on the crop insurance scheme.

Inspection and monitoring costs for commercial groves are the same as in the urban eradication scenario, $90,000 a square mile or $140 per acre.

5.2 Market effects on citrus consumers and producers from an eradication program

Consumer and producer costs are estimated as the change in welfare from changes in market quantities and prices. To estimate the changes in welfare an equilibrium displacement model was developed for the fresh market (Alston, Norton, and Pardey, 1995). While citrus products go into both the fresh and the processing sector, the processing sector is a small share, by value, of the entire citrus industry in California. California citrus products are grown primarily for the fresh market, so we focus solely on the fresh market effects.

The model shows how the equilibrium quantities, prices and other variables respond to shocks, such as the removal of acreage during an eradication program, to the system (Appendix). The model is parameterized with market and biological data.

Key parameters needed to estimate the model include the elasticities of demand and the elasticities of supply for citrus canker. Elasticities of demand are available from published reports (Huang, 1993; Kinney, et al., 1987). The relevant demand elasticities for this study are those facing California producers. Relatively little econometric analysis is available for demand facing California alone. We use estimated elasticity of demand for the United States as a whole divided by California's market share to approximate the demand elasticity facing California.

Consumers typically adjust to changes in prices relatively quickly. Therefore, we use the same demand elasticities in the short-run and long-run scenarios. We use -1.2 for oranges, -0.5 for lemons and -6.0 for grapefruit.

The elasticity of supply is also drawn from the literature. The elasticity of supply includes both yield and acreage responses. Yield responses are mostly from the movement of fruit from the processing market and into the fresh market. Producers do not adjust to changes in supply as quickly as consumers. Most supply adjustments in the short run are from changes in produce entering the fresh market from processing. We use a short-run elasticity of supply of 0.5. In the long-run, supply adjustments include shifts in fresh market fruit, yields, and acreage planted. Because producers can replant in land previously planted in citrus after a two-year host free period, in the long-run quantity supplied is responsive to changes in prices. The elasticity of supply is extrapolated from previous work and set at 4.0.

We examined infestation sizes including 500, 3,000 and 10,000 acres for lemons and grapefruit; and 3,000, 10,000, and 30,000 acres for oranges. The welfare effects to producers and consumers are calibrated on the recent three year average of production levels and prices of fresh oranges, lemons and grapefruit grown in California (Table 1).

No quarantines are imposed in the model under the eradication scenarios. While it is possible that a region or foreign country would impose a complete ban on all California products, it is expected, as with most other exotic pest infestations undergoing an eradication program, that the quarantines would be limited to fruit from the areas actually infested. Fruit would be redirected between markets so that regions that are not at risk, such as those that do not grow citrus, receive fruit from the quarantined region, and regions at risk of citrus canker invading receive clean fruit from outside the quarantined region. There could be a temporary increase in marketing costs as product is relocated. However, once the product is shifted, these costs are expected to disappear. Therefore, quarantine effects are not included.

5.3 Economic effects of establishment

The benefits of an eradication policy are from the prevention of the costs of establishment. If citrus canker were to become established then production costs would increase, and quarantines may be imposed on fresh California citrus by importing regions. Our equilibrium displacement model is used to estimate the effects of increased producer costs and quarantines on final market supply and prices. Once the new equilibrium quantity and price are determined, the changes in producer and consumer welfare are calculated.

Should citrus canker become established, producers would need to treat groves with a copper-based fungicide. In this study we assume that the fungicide, Kocide, would be applied four times a year. Kocide is registered for use in California on citrus and is registered as a treatment for citrus canker in other states. Kocide would be applied according to the label instructions and custom applied by a pest control company. The application costs would be $175 per acre. Total costs are divided by the tons produced per acre for each crop to determine the increase in the costs per ton.

In the short-run only annual costs of production would be affected. However, in the long-run, as new groves are planted, citrus canker control would affect the costs of establishing a grove. The disease must be treated beginning when the grove is first planted. All costs incurred during the first four years of establishment are investment costs and amortized over the remaining life of the grove. The increase in investment costs due to fungicide treatments would result in an increase in the annual amortization costs of establishment. Post-harvest treatments to control citrus canker include washing the fruit with SOPP or chlorine. Citrus packing plants in California already treat fruit with these materials, so there would be no additional post-harvest treatment costs.

Under the eradication policy we assume that the long-run supply elasticity would be responsive to changes in prices because eradicated acreage could be replanted in citrus. However, producer responsiveness to price changes is limited by agro-climatic or other constraints. Not all land is suitable for growing citrus, so in some areas producers may not be able to plant additional groves. Also, land planted in citrus may not be easily converted into growing other crops. Just how responsive producers are to changes in prices by making changes in production, as measured by the elasticity of supply, may affect the total costs of citrus canker establishing and who incurs those costs. To determine the effects of different supply elasticities on producer and consumer welfare, long-run supply elasticities of 1.0 percent and 4.0 percent are used in the analysis. The short-run supply elasticity is 0.5 percent. The demand elasticities are the same as under the eradication policy: -1.2 for oranges, -0.5 for lemons and -6.0 for grapefruit.

We determined the regions that would impose quarantines against California fresh citrus products by examining which countries already have citrus canker, which countries have quarantine regulations against Florida, and which U.S. states are protected by USDA quarantine regulations from the movement of Florida fresh citrus. The foreign countries and regions most likely to impose quarantines would be New Zealand, Mexico and the European Union. However, total exports to these countries are less than 1 percent of total California production, and between 1 and 2 percent of total California exports (AIC, 1999).

USDA internal quarantine restrictions for Florida prohibit the movement of fruit from quarantined areas into citrus producing states. We presume that California would be subject to the same restrictions should citrus canker become established. Industry provided data on shipments to other states. Additional data was obtained from USDA reports. For oranges the percentage is 10%, for lemons it is 12% and for grapefruit it is 6%.

The costs of quarantines are compared to the situation when no quarantines are imposed. In that case the only market shock is from an increase in production costs.

5.4 Effects on related industries

The effects on related industries depend in part upon what would be the alternative use of the land if citrus production declined as a result of citrus canker. Downstream industries include the suppliers of inputs into citrus production. Such inputs would be hired labor, and suppliers pest control services, custom crop production services and nursery stock. It is difficult to determine what the net effect would be on the demand for hired labor. If the next best crop grown on the land that used to produce citrus was more labor intensive, then the demand for labor would increase. If that crop used less labor, the demand for labor would decrease.

In general, the effects on citrus nursery stock inputs can be determined qualitatively, but again, the net effects are ambiguous depending on the degree of specialization among nursery stock producers and the alternative use of land. In the short run we would expect tree fruit planting activity to rise following an eradication program. However, the effects if citrus canker were to become established would be more difficult to determine. If producers were to move acreage out of citrus production and into another tree crop, nursery producers may be better off. If acreage is converted into row crops, then nursery producers may be worse off.

Finally, we have neglected the increased probability of adjacent States becoming infested with citrus canker should it establish in California.

6. Simulation results for alternative policies

6.1 Economic effects of eradication

Because of inspection and monitoring requirements, the minimum cost to eradicate citrus canker in an urban area would be $90,060 even if only one tree were infested (Table 2). This is for the policy option of a 125 feet eradication zone around the infested tree and no compensation paid to the homeowner. When the eradication zone is 125 feet, on average only the infested tree would need to be removed. However, the 125 feet boundary would result in a very low probability of successfully eradicating citrus canker. The minimum estimated cost of an eradication program with a 95 percent probability of eradicating citrus canker would be $102,000 when no compensation is paid. Under this policy option the boundary of the eradication zone is 1,900 feet and 199 trees are removed.

Should policy makers decide to increase the probability of successful eradication to 99 percent, the boundary of the eradication zone would need to be 3,000 feet. This results in an eradication zone of 1 square mile. Total costs would now be $120,000 (Table 2).

As the size of the infestation increases, eradication costs would also rise. It is important to note however that costs to not rise in proportion to the increase in size of the infestation as measured by the radius, but rather by area. For example, as the infestation spreads 2,500 feet from 5,000 feet to 7,500 feet, costs would increase by $421,000 compared to $1.1 million as the infestation spreads from 15,000 feet to 17,500 feet. This highlights the importance of early detection when an exotic pest enters, and the importance of containing and eradicating the infestation quickly.

Clearly, whether paid or not, compensation costs are real and ignoring them ignores the full cost of an infestation. Further, while regulatory agencies have eminent domain and can enter and remove trees as necessary to successfully eradicate an exotic pest, compensation to homeowners may also be a cost-effective policy to pursue for the agency if the compensation increases homeowner cooperation. With more cooperation regulatory agencies may eradicate the disease quicker and thereby lower direct eradication costs.

As the size of a commercial infestation increases, the eradication costs also increase (Table 3). For a 100-acre infestation, costs to inspect and monitor are $14,000 and cost to remove trees are $30,000. Because affected groves are not necessarily contiguous calculating the costs based on its spread, as measured by the radius of a circle, is not appropriate and costs are proportional to area.

Paying compensation recognizes the true costs of eradication and increases government outlays. Under the Federal Crop Insurance policy option, government outlays will increase by 660 percent from the no compensation policy. This assumes that every producer purchases crop insurance. If some producers do not purchase insurance, the cost of compensation does not disappear. The cost shifts from the government to the producer.

Federal crop insurance reimburses producers according to the predetermined actuarial value of a citrus tree. An alternative would be to pay the remaining investment value of a grove.

If compensation were paid to producers based on the investment value then government outlays would increase by 1,220 percent over the no compensation policy, but only 71 percent over the crop insurance option.

If a commercial infestation were identified before it had time to spread throughout many groves, then the destruction of groves would not have any measurable market effects. However, if many acres need to be eradicated, then the reduction in quantity supplied could cause prices to increase, and affect the welfare of consumers and producers outside of the eradication area. The reduced supply and higher prices may make producers in the eradication zone worse off, producers outside of the eradication zone better off and consumers worse off.

The percentage changes in prices and quantities as a result of a commercial eradication program are estimated for oranges, lemons and grapefruit grown in California (Table 4). Eradicating citrus trees in commercial production would decrease market supplies. The decrease in quantity supplied would cause prices to increase. In response to the increase in prices, producers plant more acres. Therefore, the net acreage reduction, in all cases, would be less than the number of acres eradicated. For example, when 15 percent of orange acreage is destroyed, in the short-run, 23 percent of the amount eradicated would be recovered through new plantings. The net effect would be a short-run decrease in orange acreage of 11.48 percent, not 15 percent (Table 4).

Similar results are observed for other levels of acres destroyed, and for lemon and grapefruit acreage. Given our assumed supply response elasticity of 4.0 and price effects, new plantings would be equivalent to 23 percent of acres removed for oranges. For lemons they would be equivalent to 29 percent and for grapefruit, 7 percent.

In the long-run producers may replant groves both within and outside the eradication zone. As the new acres start bearing fruit, market supplies would increase, causing prices to fall from the high short-run equilibrium price. For the case when 15 percent of orange acreage initially is destroyed, the net long-run decrease in acreage would be only 2.68 percent. The total amount of new plantings in the long-run after an eradication program would be 82 percent of acres removed for oranges, 86 percent for lemons and 54 percent for grapefruit. Of course, in the very long-run we may expect that the original quantity and price would be restored.

The differences in the percentage of acreage recovered through new plantings between crops are a result of the differences in the elasticity of demand. The more responsive quantity demanded is to market price, the less the price increase and the smaller the changes in acreage. Lemons had the lowest elasticity of demand and grapefruit the highest in absolute value. Consequently, prices do not increase as much for grapefruit as for lemons, and producers do not plant as much for grapefruit as for lemons.

The scope of the eradication program also influences the welfare effects on consumers and producers (Table 5). For each crop, eradication level and time period, total producer welfare decreases even though prices increase. However, not all producers would be worse off. Producers who do not eradicate benefit from the higher prices they receive for their crop. Net producer welfare would be negative because, without full compensation, the losses to producers who have groves destroyed would be greater than the benefits to producers who do not. The more acreage is removed, the greater would be the losses to consumers and producers overall. Over time, as producers replant, market supply would increase, price would fall, and the losses to consumer and producer welfare would decline.

The ability of producers to adapt to higher prices in the long-run by planting more groves would also result in consumers having a larger share in total welfare losses in the long-run than in the short-run, even though annual welfare losses for both groups would decline over time. For example, the consumer share of losses would increase from 69 percent in the short-run to 95 percent in the long-run for oranges. Note that for oranges consumers would incur the majority of the loss in total welfare, no matter which time period is being considered.

A sensitivity analysis was carried out to determine how changes in the elasticity of demand affect changes in producer and consumer welfare. The results confirm the observation that the greater the flexibility of consumers, the lower would be the costs to consumers overall. When the elasticity of demand doubles, the loss in consumer welfare would decline by 35 percent in the short-run for oranges and 11 percent in the long-run. For lemons the short-run decline in welfare loss would be 30 percent and eight percent in the long-run. Finally, for grapefruit the short-run decline in consumer welfare would be 71 percent, but only 50 percent in the long-run.

6.2 The welfare effects of citrus canker becoming established

The scenarios developed to estimate the effects of citrus canker becoming established in California look at the effects of quarantines, and rising costs of production in both the short- and long-run. Costs rise by 5 percent in the short run and 6 percent in the long run for oranges; 2 percent in the short run and 3 percent in the long run for lemons; and 4 percent in the short run and 5 percent in the long run for grapefruit. Quarantines cover 10 percent of orange demand, 12 percent of lemon demand and 6 percent of grapefruit demand.

The immediate short-run effect of quarantines is that production would be redirected from the markets imposing quarantines to all other markets. The increased supply to those markets would result in a decrease in price, even though production costs would have increased. Lower prices mean that consumers would demand more. Therefore, the increase in quantity demanded in the market not quarantined would serve to partially offset the decrease in quantity demanded from the quarantined market. The net effect is that total quantity demanded would not decrease as much as the percentage quarantined (Table 6). For example, in the fresh orange market ten percent of production would be subject to quarantines should citrus canker become established. However, the decrease in total fresh market quantity demanded would only be 6.22 percent.

Over time producers would adjust to the increased costs of production and quarantine by removing acres. The acreage removal would decrease market supplies, and prices would increase. As prices increase there would be a decline in quantity demanded in the market that did not impose quarantines. The net effect on market supply and price then would depend on how responsive producers are to changes in prices in the long run. If producers were not very responsive (i.e. the long-run elasticity of supply is 1.0), the reduction in market supplies would be less than when producers are more responsive (the long-run elasticity of supply is 4.0).

When the elasticity of supply is 1.0, producer prices would partially recover from the short-run decline, but would still be lower than at their pre-infestation level (Table 6). However, when the elasticity of supply is 4.0, producers would pull more acreage out of production than when the elasticity is 1.0. In the case of oranges, the long-run decrease in acreage would be 6.62 percent when the elasticity is 1.0 and would be 11.06 percent when the elasticity is 4.0. With the higher long-run elasticity of supply, more acreage would be pulled out of production, market supply would decrease further and market prices would rise above the pre-infestation level. For oranges, market prices would fall by 2.32 percent when the elasticity of supply is 1.0 and rise by 1.67 percent when it is 4.0 (Table 6).

Similar results are observed for lemons and grapefruit. When the supply elasticity for producers is 1.0, a portion of the quarantined production would be redirected to the market not imposing a quarantine and market prices decline. When the elasticity of supply is 4.0, producer adjustments to rising costs and quarantines would reduce fresh market supplies and prices would increase.

The differences in magnitude between the three crops depend on the percentage of the market quarantined, the percentage increase in costs, and the elasticity of demand. The larger the share of the market quarantined and the larger the percentage increase in costs, the greater the changes in welfare. The more responsive demand is to changes in prices, the greater is the percentage change in market supplies and the lower is the percentage change in price.

When no quarantine is imposed, the only shock to the system is from increases in production costs (Table 6). The increase in costs would raise prices, but not enough to completely offset the rise in costs. For example, the fresh market supply of oranges would only decrease by 1.33 percent and prices would rise by 1.1 percent in the short-run while costs would increase by 5 percent (Table 6). Consequently, producers would remove additional groves in the long run. In response, market supplies would continue to fall and prices would rise further. The fresh market supply of oranges would decrease by 2.34 percent when the long-run elasticity of supply is 1.0 and by 3.21 percent when it is 4.0. The corresponding increase in market prices would be 1.95 percent for an elasticity of 1.0 and 2.68 percent when it is 4.0.

If citrus canker becomes established the effects to producers and consumer welfare would move in opposite directions in the long run for both the quarantine and no quarantine policy responses (Table 7). California citrus producers would incur their greatest losses immediately following the establishment of citrus canker. The short-run increase in production costs and possible loss of markets would leave both consumers as a group and producers worse off.

In the long run producers would adjust by removing groves. The subsequent rise in prices would diminish the welfare losses to producers. While producer surplus would still be negative, it is less so in the long run. The more responsive producers are in the long run, the more acreage would be withdrawn from production, and the greater would be the increase in prices, and the smaller would be the decrease in producer welfare.

If quarantines are imposed the losses in producer welfare for fresh oranges would decline from $54.3 million in the short run to $38 million when the long-run elasticity of supply is 1.0, and to $12.5 million when it is 4.0 (Table 7). For lemons, the decline would be from $26 million in the short-run to $16.5 million when the long-run elasticity is 1.0 and $5 million when it is 4.0 (Table 7). For grapefruit, the losses in producer welfare would change little from the short-run period to the long run when the elasticity of supply is 1.0. In both cases the losses would be approximately $3 million, with the short-run losses slightly higher (Table 7). However, when the elasticity of supply is 4.0, the long-run loss in welfare for grapefruit producers would be only $1.7 million.

The losses to producers would be greater when quarantines are imposed than with no quarantines. The elimination of market access would impose an additional cost on producers. In the case of oranges and lemons, all losses in producer welfare would be greater when quarantines are imposed (Table 7). This is true no matter what the time period is or the long-run elasticity of supply. However, for grapefruit, when quarantines are imposed and producers are more responsive to changes in prices the decrease in welfare would not be as high as when no quarantine is established, but producers are relatively restricted in their ability to respond to changes in prices. When a quarantine is imposed and the elasticity of supply is 4.0, the decrease in producer welfare would be $1.7 million. However, when no quarantine is imposed and the elasticity of supply is 1.0, the decrease in producer welfare would be $2.2 million.

While the losses to producer welfare would decrease over time, the losses to consumer welfare would increase. This applies to the case when quarantines are imposed and when they are not. In the long run, as acreage is removed, quantity supplied would fall and prices would increase in comparison to the short-run effects. Therefore, the losses in consumer welfare would increase over time. However, which consumer groups would incur those losses depends upon the policy response of importing regions. If quarantines are imposed, then the quarantine results in a division of the market for fresh citrus. The market imposing the quarantine would experience a reduction in supply and an increase in prices. The remaining market may experience an increase in supply and a reduction in prices depending upon how producers respond to the relative changes in costs and prices in the long run.

The regions most likely to quarantine California citrus should citrus canker become established are other citrus producing states in the U.S. These states include Arizona, Texas and Florida. Consequently, consumers in those regions would experience a loss in consumer welfare. Consumers in the remaining states and foreign consumers may benefit from the establishment of citrus canker when quarantines are imposed. In the short-run producers would not immediately respond to the higher production costs and quarantines by removing acres. Farm output would be redirected to the remaining markets and prices would fall. Consumers in the remaining market would now be better off.

In the long run quantity supplied would decrease as acres are removed from production and prices would rise. When the elasticity of supply is 1.0, and producers are not very responsive to changing prices, the decrease in quantity supplied would be less than the decrease in demand. This means that there would be some production that still needs to be redirected to the remaining markets. Quantity supplied to those markets would increase and prices would fall. Therefore, consumers would also be better off in the long run in the market that does not impose quarantines. However, if the elasticity of supply is 4.0 and producers are relatively more responsive to changes in prices, then enough acreage would be pulled out of production so that quantity supplied to the domestic and foreign markets not imposing quarantines would actually decline. Consequently, prices would rise and consumers in that market would now be worse off in the long run.

For example, consumers in California are obviously part of the region that would not impose quarantines. California consumer welfare for fresh oranges would increase by $9.7 million in the short run and by $3 million in the long run when the elasticity of supply is 1.0. When the long-run elasticity of supply is 4.0, consumer welfare would decrease by $4.5 million. However, when quarantines are imposed, all consumers in the U.S. would incur a net loss of $138 million in the short run and $172.5 million in the long run when the elasticity of supply is 1.0. In these two cases the losses to consumers in the quarantined regions would be greater than the gains to consumers outside of those regions. When no quarantine is imposed all consumers would be worse off following the establishment of citrus canker in California, because all consumers would face higher prices for citrus.

Total producer and consumer welfare losses would be smaller when no quarantine is established than when one is. For oranges and lemons, the change would be an order of magnitude greater when quarantines are imposed than when none exist (Table 7). For grapefruit, it would be only slightly higher. The percentage of production quarantined is smallest for grapefruit and demand is also the most elastic in that market. The percentage of production quarantined is greatest for lemons, and the demand for lemons is inelastic. Therefore, welfare losses would increase by only 50 percent in the grapefruit market when quarantines are imposed, yet would increase by up to 1550 percent in the lemon market (Table 7).

Which group incurs the greatest percentage of losses in total welfare would depend upon the responsiveness of producers and consumers to changes in prices, and the policy response of importing regions. When producers are more responsive, the percentage of their losses in total welfare losses would decrease. The same would apply to consumers. As the consumer's responsiveness to changes in price increases, their share of total welfare losses would decrease. Furthermore, when quarantines are imposed, the losses to producer welfare would account for a larger percentage of total welfare losses than when none are imposed. For example, among California producers and consumers of oranges and lemons, producers would have the greater percentage of total welfare losses except for the case where no quarantines are imposed and the long-run elasticity of supply is 4.0 (Table 7). Grapefruit producers would always have the greatest percentage due to the high responsive of consumers to changes in the price of grapefruit. When all consumers and producers of California citrus are considered, consumers would always have the greater percentage of total welfare losses.

6.3 Full assessment of costs and benefits

This section compares the costs of eradication to the benefits of preventing the costs of establishment for California separately and for the United States as a whole. The analysis considers the costs and benefits to California producers, consumers and taxpayers, and to all U.S. citrus producers, consumers and taxpayers.

We consider eradication costs for both a relatively small and a relatively large infestation. The small infestation case is 20 square miles in an urban area and is equal to the size of the Florida infestation when it was first identified. The commercial acreage is set at 100 acres. The large infestation case is 400 square miles in an urban area and is equal to the size of the Florida infestation in December 1999. In the large infestation the commercial acreage affected is set at 3,000 acres.

Eradication costs are equal to government outlays necessary to achieve a 95 percent or a 99 percent probability of successfully eliminating citrus canker in an urban area plus the government outlays of the commercial eradication programs. Given the large number of scenarios, here we report only those outlays based on compensation policies as of December 1999. For the urban eradication program, no compensation is paid to homeowners. For the commercial eradication program the outlays include paying crop insurance claims. We have assumed the outbreak occurs in lemons because lemons are more susceptible to citrus canker than oranges or grapefruit.

In the large infestation case, the loss of 3,000 acres of citrus production in the large eradication program will affect market supplies and prices. The net present value of changes in producer and consumer welfare is then added to the costs of government programs to estimate total eradication costs. The net present value of all costs is calculated for an eight-year adjustment period. Each year the elasticity of supply is raised from a starting value of 0.5 in the first year to the long-run equilibrium value of 4.0 in year 8. Eight years was chosen as it allowed sufficient time for producers to plant and have those trees start bearing fruit. At year nine the original equilibrium is restored, and costs and benefits from then on are zero. A discount rate of seven percent is used to convert future costs and benefits into current values.

The costs to producers and consumers for the United States as a whole include the costs and benefits to producers and consumers of California citrus, and to producers and consumers of citrus produced in other states. Producers and consumers of citrus produced in other states are also affected by a large program to eradicate citrus canker because changing citrus supplies would raise market prices. Producers would benefit from the higher prices. Consumers, including those in California, would be worse off.

In the simulations the allocation of government outlays between state and federal regulatory agencies is based on current practices for other plant diseases. Inspection, monitoring and tree removal costs are divided equally between the federal and state regulatory agencies. Federal agencies pay all compensation.

The net present value for costs of citrus canker becoming established is estimated in order to compare it to the net present value of all eradication costs. The net present value of the costs of establishment is also calculated for an eight-year adjustment period. Each year the elasticity of supply is raised from 0.5 in the first year to the long-run equilibrium values of 1.0 or 4.0 in year eight. The costs and benefits from year nine into perpetuity are set at the long-run equilibrium values estimated in year eight. The costs and benefits are determined for all U.S. producers and consumers of U.S. citrus products and for California producers and consumers for comparison with the eradication costs.

It is never known with certainty whether an eradication program will be successful. Therefore, the costs of the alternative eradication programs, small infestation or large, 95 percent probability of success or 99 percent, need to be compared to the expected benefits. The expected benefits of eradication are equal to the costs imposed from establishment multiplied by the probability of successfully eradicating citrus canker.

The total costs to eradicate citrus canker include the costs to regulatory agencies, plus the net present value of the losses in welfare to producers and consumers. Total government outlays for a small eradication program that has a 95 percent probability of success would be $3.6

million (Table 8). California would contribute $1.6 million, or 44 percent to total outlays. Because the U.S. government pays compensation, its outlays would be higher and account for 56 percent of total outlays. Increasing the probability of success to 99 percent would increase outlays by $0.5 million, or 13 percent. For the large infestation total outlays would be $61.6 million in order to achieve a 95 percent probability of success. California would contribute about 43 percent to total outlays. Total government expenditures would need to increase by only 3 percent, or $1.85 million, to increase the probability of success to 99 percent.

The eradication program associated with a large area would also result in changes in commercial production to the extent that market prices would be affected. Therefore, all producers and consumers of citrus in California and in the United States would be affected. The net present value of welfare changes to all producers and consumers in California would range from $54.7 million for lemons to $74.3 million for oranges (Table 9). Losses to producers account for the majority of total losses for all crops among Californian consumers and producers. Total welfare changes to all producers and consumers of citrus in the U.S. would range from $140.2 million for oranges to $231.3 million for lemons. For the U.S. as a whole, losses to consumers would account for the majority of total losses for all crops.

The costs of eradication must be compared to the costs of establishment. If citrus canker were to become established, the net present value of total welfare losses to California producers and consumers for fresh oranges would range from a high of $628 million when a quarantine is imposed and the long-run elasticity of supply is 1.0, to a low of $135 million when no quarantines are imposed and the elasticity of supply is 4.0 (Table 10). Note, when quarantines are imposed and the elasticity of supply is 1.0, California orange consumers would be better off when citrus canker establishes within the state.

The effects on California lemon and grapefruit producers and consumers show similar results (Table 10). Total losses would range from a high of $218 million for lemons and $44 million for grapefruit to a low of $16 million for lemons and $22 million for grapefruit. In the case of lemons, California consumers would always be better off when citrus canker becomes established and quarantines are imposed (Table 10).

U.S. producer and consumer welfare losses would range from a high of $3,274 million for oranges, $2,821 for lemons and $122 million for grapefruit to a low of $701 million for oranges, $84 million for lemons and $51.6 million for grapefruit. Which scenario results in the highest and lowest values; however, depends upon the crop. For example, when quarantines are imposed on grapefruit and the elasticity of supply is 1.0, total welfare losses would be lowest. Total welfare losses would be greatest when quarantines are imposed and the elasticity of supply is 4.0. When producers are relatively unresponsive to price changes, quarantined supply would be redirected to the remaining markets, market prices would fall, and producers in other states would also be negatively affected by the fall in prices. Lower prices would increase consumer welfare in states where commercial citrus production does not occur, so that total U.S. consumer welfare would be positive. When producers are more responsive and California production decreases so that total U.S. market supply is lower, market prices would increase and producers in other states would be better off; however, consumers are much worse off.

Total losses to all citrus crops for producers and consumers within California would range from a high of $890 million to a low of $173 million (Table 11). For all U.S. producers and consumers the net present value of total welfare losses would be over $5 billion when quarantines are imposed and between $920 million and $960 million when they are not. The expected value of the establishment costs is calculated for a 95 percent probability of success and a 99 percent probability to properly compare the benefits of eradication to the costs. Total costs of eradication include government outlays plus the changes in producer and consumer welfare during a large eradication program. Because it is unknown which crops would be affected by an invasion and eradication program, the effects on producers and consumer of each crop in an eradication program should not be added together. Also, when aggregating the producer and consumer losses with government outlays, the compensation to producers needs to be deducted from the total losses to producers. For purposes of comparison to the costs of establishment, the losses in welfare to producers and consumers from an eradication program for lemons is included as lemons are more susceptible to citrus canker than oranges or grapefruit.

The full expected benefits for the United States of eradicating citrus canker in California would be greater than the full economic costs of eradication (Table 12). This holds even when the size of the infestation is relatively large to begin with, and for both the 95 percent and 99 percent probabilities of success. For a large eradication program that would achieve a 95 percent probability of success, the benefits within California would be twice as large as the costs for the best-case scenario where no quarantines are imposed and producers are relatively responsive to changes in prices. The benefits would be over 10 times as large for the worse case scenario where quarantines are imposed and producers are relatively unresponsive to price changes. The net benefits (expected benefits less costs) would be $83 million for the best-case scenario and $837.5 million for the worst case, for a 95 percent probability of success.

The benefits of eradication would also be greater than the costs for the U.S. as a whole, even for a large eradication program. The costs of establishment would be three times greater than the costs of eradication at the 95 percent probability level for the best case scenario of no quarantines and producers relatively unresponsive to price changes. Under the worse case scenario of quarantines and producers relatively unresponsive to price changes the expected benefits would almost be 19 times greater than the costs.

The additional expected benefits of increasing the probability of success to 99 percent would also be greater than the additional costs both within California and for the U.S. For the case of the large eradication program the additional costs would be $925,000 for California government outlays and losses in welfare. The additional expected benefits would be $7 million under the best-case scenario and $35.6 million for the worst case.

The gains of eradication for the entire U.S. would be even greater. Increasing the probability of success to 99 percent causes total U.S. costs to increase by $1.8 million. Benefits would increase by $38.7 million under the best-case scenario and by $231 million under the worst case.

One option not included in this study would be the cost and benefit of a second eradication program should the first one fail. The costs and benefits of a second program would be highly variable depending upon the reason the first one failed. If the first one failed because a few trees were missed and the infestation was discovered quickly, then the costs of a second eradication program would be similar to the costs of a small eradication program. Even just using the 95 percent probability of success, the probability of failing a second time would be 0.05 * 0.05 or .0025, which is approximately equal to zero. However, if the eradication program fails because the disease spread faster than trees could be destroyed, then costs would be even greater than in the first program. In this case, a whole new program would have to be evaluated and the costs and benefits estimated for a 95 percent probability of success and a 99 percent probability of success.

7. Discussion and implications

The most epidemiologically significant way that citrus canker is likely to be introduced into California is via infected planting stock and/or other propagative material (except seeds). Clinically or sub-clinically *Xcc*-infected fruit with lesions or asymptomatic *Xcc*-infested fruit would not likely be sources for establishment of the pathogen in California. Environmental conditions in California are generally conducive to *Xcc* infection and Citrus canker development. However, the likely rate of spread of any infestation and the extent of infection in California are largely unknown at this time. Introduction and establishment of the citrus leaf miner in California could exacerbate leaf infection. Along with adequate resources (i.e. funds, personnel), and broad-based industry and public support, a sound biologically-based regulatory policies would be needed to implement effective measures to minimize the effects of any infestation in California. Nevertheless, decisive and resolute measures would have to be taken in a timely manner. Regulatory policies and actions would also have to be harmonious with current policies of the USDA and international Plant Protection Organizations for protecting citrus production in the U.S. and in other citrus-growing areas around the world.

Other timely policy decisions regarding eradication versus disease management (e.g. copper-containing sprays, windbreaks, establishment of citrus canker-free areas) would be needed. The choice of policy depends upon the relative costs and benefits of the alternative disease management choices. The relative costs and benefits of eradication as opposed to establishment depend on how soon the infestation is identified and how quickly regulatory agencies can cooperate with homeowners and producers to destroy affected trees. Nonetheless our results show that the gains from eradication far exceed the costs of allowing citrus canker to become established.

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Appendix: Analysis of market effects

For both the eradication and establishment scenarios, producers and consumers may be affected through changes in supply, production costs and quarantines. Models were developed to reflect how these shocks affected total quantities supplied and demanded, and the price for those commodities.

The basic approach used in these models sets out supply and demand conditions in log-differential form such that $dlnX = (X_1 - X_0)/X_0 = \hat{X}$, where the subscript 1 indexes the new level and the subscript 0 indexes the original level of variable X. We use the model to show how the equilibrium quantities, prices and other variables respond to shocks, such as the removal of acreage during an eradication program, or quarantines and increases in production costs when an exotic pest becomes established, to the system. The model is parameterized with market and biological data.

The model has three parts. The first part describes the demand side of the market, the second describes the supply side of the market and the third describes the equilibrium conditions between quantities and prices.

Consumers are separated into two groups, consumers in the market that does not impose the quarantine, D_{nq}, and consumers in the market that will impose quarantines if an exotic pest becomes established, D_q. Equation (1.1) states that the quantity demanded in the market that is not quarantined depends upon the retail price, P_r, of the commodity. The log-differential form states that the percentage change in the quantity demanded is equal to the elasticity of demand, η_{P_r}, times the percentage change in retail price. The elasticity of demand is negative to reflect the fact that as price increases, consumers will buy less of the commodity.

(1.1) $D_{nq} = d_{nq}(P_r)$ (1.1a) $\hat{D}_{nq} = ¦_{P_r}\hat{P}_r$

Equation (1.2) states that the change in quantity demanded in the region that will potentially impose a quarantine only depends on the demand shock, $\hat{¤}$. If a commodity is banned from entering a region, then it is as though the price is infinitely high in that market. When quarantines are imposed, $\hat{¤}$ is equal to -1.0.

(1.2) $D_q = d_q(¤)$ (1.2a) $\hat{D}_q = \hat{¤}$

Equation (1.3) states that the total quantity demanded is equal to the quantity demanded in each region. The log-differential form states that the total percentage change in demand is equal to the percentage change in demand in the area not quarantined times the original share, $¢$, of the commodity that is consumed in the market not quarantined, plus the percentage change in demand in the quarantine market, times the original share of commodity consumed in that market before the pest invasion.

(1.3) $D = D_{nq} + D_q$ (1.3a) $\hat{D} = ¢\left(¦_{P_r}\hat{P}_r\right) - (1 - ¢)$

Total quantity supplied to the market, X_g, is given by equation (1.4). Quantity supplied is equal to marketable yield per acre, Y, multiplied by the number of acres, L, in production. Therefore, the percentage change in quantity supplied is equal to the percentage change in yield per acre plus the percentage change in acreage.

(1.4) $X_g = Y * L$ (1.6a) $\hat{X}_g = \hat{Y} + \hat{L}$

Equation (1.5) states that the marketable yield per acre depends upon the producer price received for the good, P_g, the costs of inputs, W, and external yield decreases, $³Y$. The percentage change in marketable yields is equal to the percentage change in the producer price multiplied by the yield elasticity of quantity supplied, $£_{YP_g}$, with respect to producer prices, plus the percentage change in input costs multiplied by the yield elasticity of quantity supplied with respect to input costs, $\pounds_{YW}$, plus any percentage decreases in yield caused by an exotic pest or disease.

(1.5) $Y = y(P_g, W; {}^{3}{}_{Y})$ (1.5a) $\hat{Y} = \pounds_{YP_g}\hat{P}_g + \pounds_{YW}\hat{W} + \hat{{}^{3}}_{Y}$

The yield elasticity of supply with respect to producer prices is positive. As prices increase, marketable yields increase. The yield elasticity of supply with respect to input costs is negative. As input costs increase, producers decrease yields.

In general we expect that the supply response to changes in prices and input costs through changes in yields are not large in percentage terms. Larger supply responses typically occur through moving land in and out of production of different commodities as relative prices change.

Equation (1.6) characterizes the acreage response to changes in producer prices, input costs and external acreage shocks, ${}^{3}{}_{L}$. The percentage change in acreage cultivated is equal to the percentage change in price multiplied by the acreage elasticity of supply with respect to output prices, $\pounds_{LP_g}$, plus the acreage elasticity of supply with respect to input prices, $\pounds_{LW}$, plus any external changes in acres cultivated due to an exotic pest invasion. Again the elasticity with respect to output prices is positive and is negative with respect to input costs. External changes in acres occur when crops are destroyed during an eradication program.

(1.6) $L = l(P_g, W, {}^{3}{}_{l})$ (1.6a) $\hat{L} = \pounds_{LP_g}\hat{P}_g + \pounds_{LW}\hat{W} + \hat{{}^{3}}_{L}$

Equation (1.7) states that quantity supplied must equal quantity demanded. Therefore, in the log-differential form the percentage change in quantity supplied must equal the percentage change in quantity demanded.

(1.7) $X_g = D$ (1.7a) $\hat{X}_g = \hat{D}$

Equation (1.8) gives the equilibrium conditions for prices in California. It states that the average California port price of a commodity is equal to the grower price plus all marketing costs. Marketing costs include all handling, packinghouse, post-harvest treatment and transportation costs within California.

Many of the commodities analyzed in the case studies are marketed by cooperatives. The cooperative sets a fixed cost per unit handled (i.e. dollars per carton). Once the cost is fixed for a season, the price received by the growers is equal to the price received by the cooperative less the fixed handling cost. Data on prices received by a marketing cooperative are not readily available, therefore, in empirical implementation the California port price is used. This price reflects all marketing costs plus transportation costs from the producer to the border.
The percentage change in the port price is equal to the percentage change in grower prices, multiplied by the grower price to export price ratio, $\cdot_g$ plus the percentage change in marketing costs multiplied by the marketing cost to export price ratio, $\cdot_m$.

(1.8) $P_e = P_g + P_m$ (1.8a) $\hat{P}_e = \cdot_g \hat{P}_g + \cdot_m \hat{P}_m$

Finally, equation (1.9) shows that consumer retail prices are a percentage mark-up of the California export price. While there are some fixed transportation costs in bringing supplies to consumers, it is assumed in this model that increases in prices from the border to the market shelf occurs mainly from mark-ups at the retail level.

(1.9) $P_r = aP_e$ (1.9a) $\hat{P}_r = \hat{P}_e$

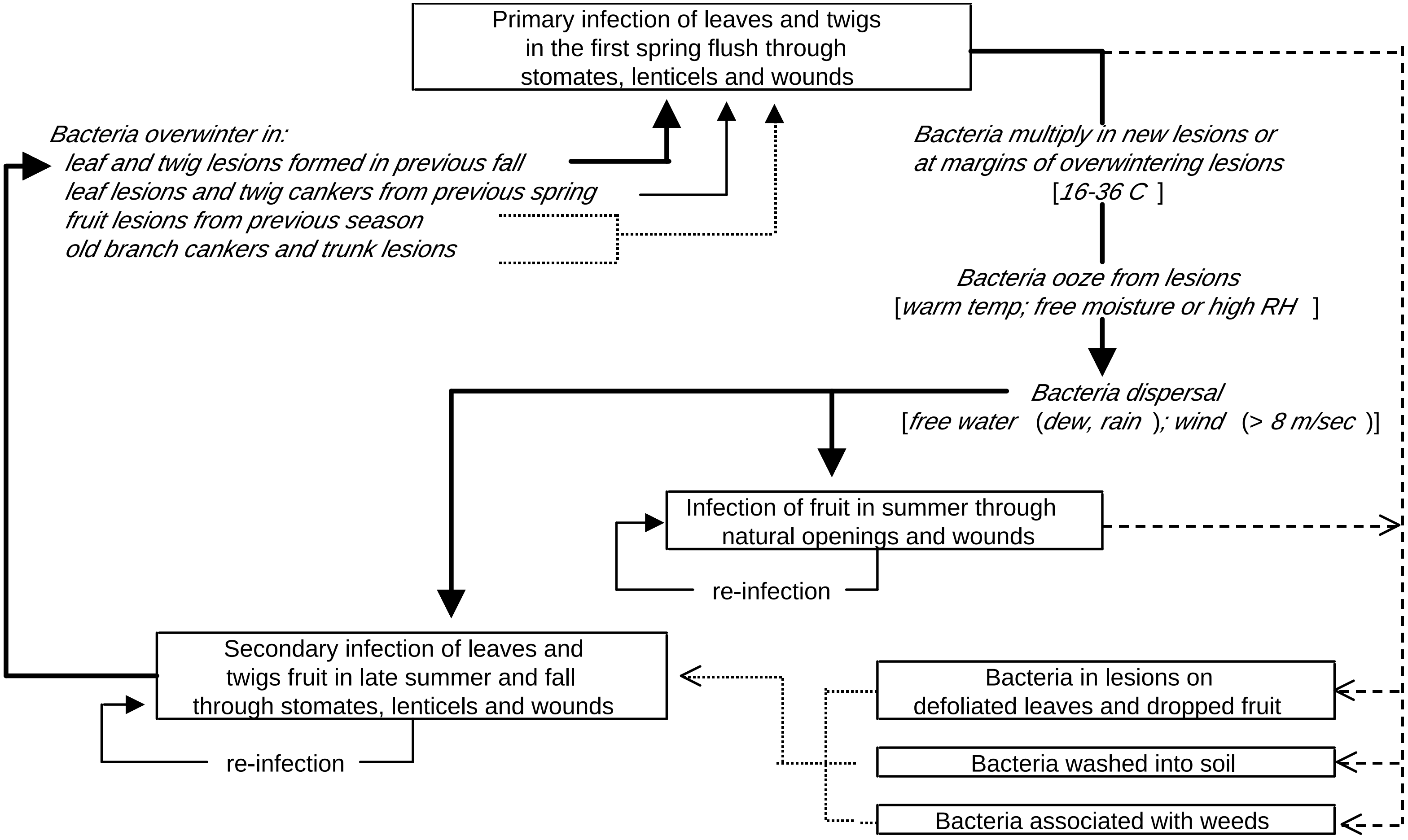

Figure 1. Disease cycle of citrus bacterial canker caused by *Xanthomonas campestris* (=*axonopdis)* pv. *citri*).

➡ = main infection; → = minor infection; ⋯▶ = neglible infection

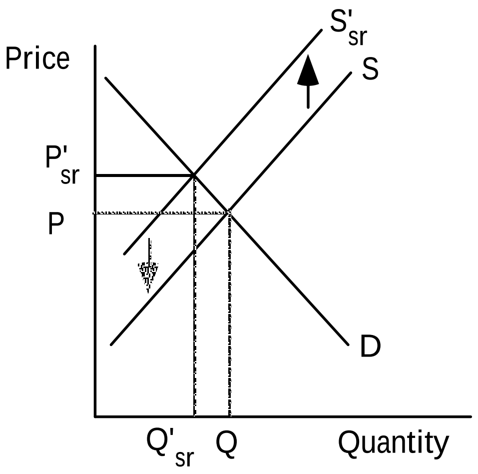

Figure 2. Short-run Equilibrium Adjustments - Eradication Scenario

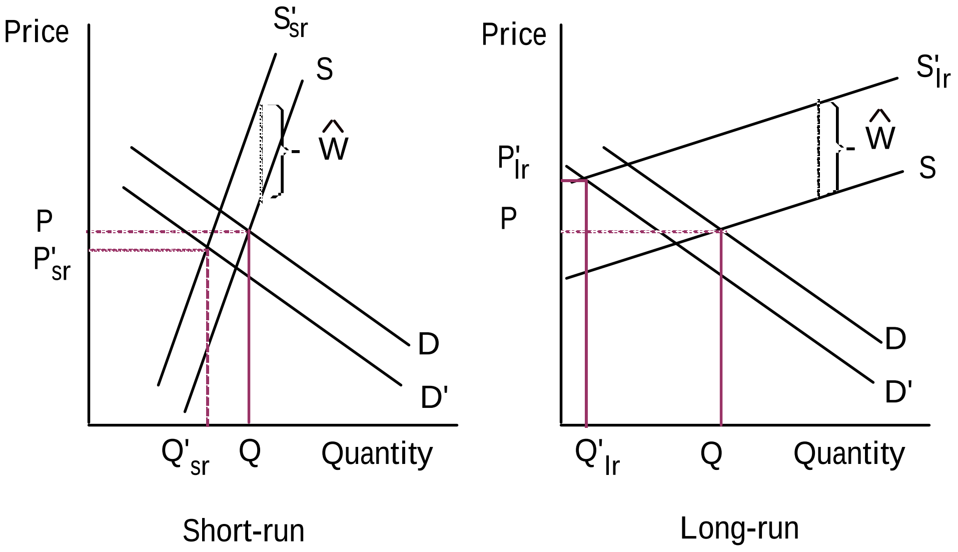

Figure 3. Short-run and Long-run Equilibrium Adjustments - Establishment Scenario

Table 1. Average Production and Prices of California's Top Three Citrus Crops*

	Oranges	Lemons	Grapefruit
Acreage	200,567	48,300	17,133
Yield	9.4	8.3	11.6
Supply (short tons)	1,893,931	369,000	65,333
California Share of U.S. Supply	74%	85%	14%
California Producer Price	238	439	300
Export Price	510	609	605
Retail Price	1,253	2,333	1,120

*Three year moving average, 1997-1999. Source: USDA.

Table 2. Minimum Eradication Costs for Citrus Canker in an Urban Setting*

				Costs with Compensation	
Radius (feet)	Square miles	Number of Trees	Costs with no compensation ($)	Voucher ($20/tree)	Appraised Value ($400/tree)
125	0.002	1	60	80	460
1,900	0.41	199	11,966	15,955	91,742
3,000	1	497	29,833	39,777	228,720
5,000	3	1,400	83,000	110,000	635,000
15,000	25	12,400	746,000	994,000	5,718,000
20,000	45	22,100	1,326,000	1,768,000	10,165,000

*Monitoring and inspection costs are $90,000 per square mile.

Table 3. Costs for Citrus Canker Eradication in a Commercial Setting as Size of Infestation Increases

Acres	Tree Removal with no compensation ($300/acre)	Tree removal with Compensation Insurance ($2,916+$300/ac)	Capital Value of Orchard ($5,300+$300/ac)	Inspection and Monitoring Costs ($140/ac)
	- - - - - - - - - - - - - - - - - -	- (000) -	-	- - - - - - - - - - - - -
1	0.30	3.22	5.60	0.14
100	30	322	560	14
300	90	965	1,680	42
3,000	900	9,648	16,800	420
30,000	9,000	96,480	168,000	4,200

Table 4. Production and Price Effects of Eradicating Citrus Canker from Commercial Groves

Acres Eradicated	Percentage of Total Acres in California	Elasticity of Supply	Elasticity of Demand	Acres	Yield	Quantity	Producer Prices	Retail Prices
Oranges				- - - - - - - - - -		% change	- - - - - - - - - -	
3,000	1.5	0.5	-1.2	-1.15	0.35	-0.80	1.41	0.66
10,000	5	0.5	-1.2	-3.83	1.18	-2.65	4.70	2.21
30,000	15	0.5	-1.2	-11.48	3.52	-7.95	14.10	6.63
3,000	1.5	4	-1.2	-0.27	0.08	-0.19	0.33	0.15
10,000	5	4	-1.2	-0.89	0.27	-0.62	1.10	0.51
30,000	15	4	-1.2	-2.68	0.82	-1.85	3.29	1.55
Lemons				- - - - - - - - - -		% change	- - - - - - - - - -	
500	1	0.5	-0.5	-0.71	0.29	-0.42	1.16	0.84
3,000	6.2	0.5	-0.5	-4.40	1.80	-2.60	7.21	5.19
10,000	21	0.5	-0.5	-14.90	6.11	-8.79	24.42	17.58
500	1	4	-0.5	-0.14	0.06	-0.08	0.23	0.17
3,000	6.2	4	-0.5	-0.87	0.36	-0.51	1.42	1.02
10,000	21	4	-0.5	-2.94	1.20	-1.73	4.82	3.47
Grapefruit				- - - - - - - - - -		% change	- - - - - - - - - -	
500	3	0.5	-6	-2.79	0.21	-2.57	0.86	0.43
3,000	17.5	0.5	-6	-16.25	1.25	-15.00	5.00	2.50
10,000	58	0.5	-6	-53.86	4.14	-49.71	16.57	8.29
500	3	4	-6	-1.39	0.11	-1.29	0.43	0.21
3,000	17.5	4	-6	-8.13	0.63	-7.50	2.50	1.25
10,000	58	4	-6	-26.93	2.07	-24.86	8.29	4.14

Table 5: Welfare Effects of Eradication in the Market for California Citrus

Acres	Elast. Supply	Total Producer Welfare ($) (000)	Share of Producer Rev. (%)	Producer Welfare- Land not Infested ($) (000)	Calif. Cons. Welfare ($) (000)	U.S. Cons. Welfare ($) (000)	Global Cons. Welfare ($) (000)	Share of Cons. Costs (%)	Total Welfare ($) (mil)
Oranges									
3,000	0.5	-7,140	-1.58	6,282	-1,785	-10,727	-15,660	-0.66	-22.8
10,000	0.5	-23,580	-5.23	20,370	-5,896	-35,428	-51,720	-2.18	-75.3
30,000	0.5	-68,830	-15.27	56,250	-17,214	-103,435	-151,000	-6.36	-219.8
3,000	4	-209	-0.05	1,469	-417	-2,508	-3,662	-0.15	-3.9
10,000	4	-694	-0.15	4,799	-1,389	-8,343	-12,180	-0.51	-12.9
30,000	4	-2,069	-0.46	13,570	-4,140	-24,879	-36,320	-1.53	-38.4
Lemons									
500	0.5	-1,472	-0.84	2,034	-790	-5,632	-7,822	-0.84	-9.3
3000	0.5	-9,027	-5.12	12,140	-4,845	-34,538	-47,970	-5.12	-57.0
10000	0.5	-29,610	-16.81	36,610	-15,897	-113,328	-157,400	-16.81	-187.0
500	4	-36	-0.02	402	-156	-1,113	-1,546	-0.17	-1.6
3000	4	-225	-0.13	2,421	-966	-6,885	-9,562	-1.02	-9.8
10000	4	-757	-0.43	7,521	-3,251	-23,177	-32,190	-3.44	-33.0
Grapefruit									
500	0.5	-3,036	-5.08	498	-64	-532	-945	-0.42	-4.0
3000	0.5	-16,590	-27.74	2,504	-351	-2,907	-5,163	-2.31	-21.8
10000	0.5	-44,680	-74.72	4,573	-945	-7,826	-13,900	-6.23	-58.6
500	4	-191	-0.32	251	-32	-268	-475	-0.21	-0.7
3000	4	-1,079	-1.8	1,308	-183	-1,512	-2,686	-1.2	-3.8
10000	4	-3,254	-5.44	2,902	-551	-4,560	-8,100	-3.63	-11.4

Table 6. Production and Price Changes from the Establishment of Citrus Canker –

Quarantine	Time Period	Supply Elasticity	Producer Prices	Retail Prices	Quantity Area Not Quarantined	Yield	Acreage	Quantity
Oranges			- - - - - - - - - - - - % change - - - - - - - - - - - -					
10%	Short run	.5	-7.44	-3.50	4.20	-3.11	-3.11	-6.22
10%	Long run	1	-2.32	-1.09	1.31	-2.21	-6.62	-8.82
10%	Long run	4	3.55	1.67	-2.00	-0.74	-11.06	-11.80
0	Short run	.5	2.35	1.10	n/a	-0.66	-0.66	-1.33
0	Long run	1	4.16	1.95	n/a	-.59	-1.76	-2.34
0	Long run	4	5.70	2.68	n/a	-0.20	-3.01	-3.21
Lemons								
12%	Short run	.5	-13.47	-9.70	4.85	-3.87	-3.87	-7.73
12%	Long run	1	-6.84	-4.92	2.46	-2.46	-7.38	-9.84
12%	Long run	4	0.00	0.00	0.00	-0.75	-11.25	-12.00
0	Short run	.5	1.16	0.84	n/a	-0.21	-0.21	-0.42
0	Long run	1	2.21	1.59	n/a	-0.20	-0.6	-0.79
0	Long run	4	2.75	1.98	n/a	-0.06	-0.93	-0.99
Grapefruit								
6%	Short run	.5	-1.21	-0.60	3.61	-1.30	-1.30	-2.60
6%	Long run	1	-0.26	-0.13	0.79	-1.32	-3.95	-5.26
6%	Long run	4	2.05	1.03	-6.16	-0.74	-11.05	-11.79
0	Short run	.5	0.57	0.29	n/a	-0.86	-0.86	-1.71
0	Long run	1	1.25	0.63	n/a	-0.94	-2.81	-3.75
0	Long run	4	2.86	1.43	n/a	-0.54	-8.04	-8.57

Table 7: Welfare Effects for California Citrus from the Establishment of Citrus Canker

Quar.	Sup. Elast.	Prod. Welf. ($)	Share of Rev. (%)	Calif. Cons. Welf. ($mil)	Share of Costs (%)	Total Calif. Welf. ($mil)	U.S. Cons. Welf. ($mil)	Share of Costs (%)	All U.S. ($mil)	Global Cons. Welf. ($mil)	Share of Costs (%)	Total Welf. ($mil)
Oranges												
10%	0.5	-54.3	-12.1	9.7	3.6	-44.7	-138.0	-8.5	-192.0	-111.2	-4.7	-165.5
10%	1	-38.0	-8.4	3.0	1.1	-35.0	-172.5	-10.6	-210.5	-164.3	-6.9	-202.3
10%	4	-12.5	-2.8	-4.5	-1.7	-17.0	-210.9	-13.0	-223.4	-223.3	-9.4	-235.8
0	0.5	-11.9	-2.6	-3.0	-1.1	-14.8	-17.8	-1.1	-29.7	-26.0	-1.1	-37.9
0	1	-10.4	-2.3	-5.2	-1.9	-15.7	-31.4	-1.9	-41.8	-45.8	-1.9	-56.3
0	4	-3.6	-0.8	-7.1	-2.6	-10.7	-42.8	-2.6	-46.4	-62.5	-2.6	-66.1
Lemon												
12%	0.5	-26.2	-14.9	9.4	10.0	-16.8	-154.7	-23.0	-180.9	-128.7	-13.7	-154.9
12%	1	-16.5	-9.4	4.7	5.0	-11.8	-183.0	-27.1	-199.4	-169.9	-18.1	-186.4
12%	4	-5.0	-2.8	0	0.0	-5.0	-211.2	-31.3	-216.2	-211.2	-22.6	-216.2
0	0.5	-1.5	-0.8	-0.8	-0.8	-2.3	-5.6	-0.8	-7.1	-7.8	-0.8	-9.3
0	1	-1.4	-0.8	-1.5	-1.6	-2.9	-10.7	-1.6	-12.0	-14.8	-1.6	-16.2
0	4	-0.4	-0.2	-1.9	-2.0	-2.3	-13.3	-2.0	-13.7	-18.5	-2.0	-18.9
Grapefruit												
6%	0.5	-3.1	-5.1	0.09	0.6	-3.0	-1.5	-1.2	-4.5	-0.9	-0.4%	-3.9
6%	1	-3.1	-5.1	0.02	0.1	-3.0	-2.0	-1.7	-5.1	-1.9	-0.8%	-5.0
6%	4	-1.7	-2.8	-0.2	-1.0	-1.8	-3.3	-2.8	-4.9	-4.3	-1.9%	-5.9
0	0.5	-2.0	-3.4	-0.04	-0.3	-2.1	-0.4	-0.3	-2.4	-0.6	-0.3%	-2.7
0	1	-2.2	-3.7	-0.09	-0.6	-2.3	-0.8	-0.6	-3.0	-1.4	-0.6%	-3.6
0	4	-1.2	-2.1	-0.2	-1.4	-1.4	-1.7	-1.4	-2.9	-3.1	-1.4%	-4.3

Table 8. Government Costs to Eradication Citrus Canker from California

Initial Infestation	Eradication Boundary	Urban Square miles	Comm. Acreage	Costs Urban	Comm.	Calif.	U.S.	Total
	(feet)			- - - - - - - - - - -		($000)	- - - - - - - - - - -	
Small	1900	27	100	3,192	364	1,632	1,924	3,556
	3000	31	100	3,665	364	1,868	2,160	4,028
Large	1900	432	3000	51,577	10,068	26,448	35,196	61,645
	3000	447	3000	53,426	10,068	27,373	36,121	63,494

Table 9. Present Value of Changes in Producer and Consumer Welfare for a Commercial Eradication Program

	California			U. S.		
Crop	Producers	Consumers	Total	Producers	Consumers	Total
	- - - - - - - -	- - - - - - - -	($000)	- - - - - - - -	- - - - - - - -	
Oranges	-68,307	-6,004	-74,311	-64,049	-71,892	-140,199
Lemons	-38,727	-15,963	-54,690	-31,714	-192,600	-231,328
Grapefruit	-67,389	-1,914	-69,304	-27,985	-120,068	-187,458

*The discount rate is 7% and 3,000 acres are eradicated.

Table 10. Present Value of Welfare Changes if Citrus Canker were to become Established*

		California			U.S.		
Fresh Oranges							
		($mil)					
Quarantine	Supply Elasticity	Producers	Consumers	Total	Producers	Consumers	Total
Yes	1	-696.0	68.1	-628.0	-745.8	-2,156.9	-2,902.7
Yes	4	-352.7	-3.2	-355.9	-348.1	-2,925.9	-3,274.0
No	1	-153.0	-55.2	-208.1	-115.1	-585.9	-701.0
No	4	-68.8	-66.5	-135.3	-17.8	-786.2	-804.0
Fresh Lemons							
Yes	1	-325.5	107.3	-218.2	-361.0	-2,459.9	-2,820.9
Yes	4	-179.1	39.2	-139.9	-194.5	-1,785.3	-1,979.8
No	1	-19.6	-18.9	-38.5	-13.1	-157.8	-170.8
No	4	-8.1	-7.8	-15.9	-0.1	-83.9	-84.0
Grapefruit							
Yes	1	-44.7	0.7	-44.0	-57.5	5.9	-51.6
Yes	4	-28.6	-1.3	-29.8	-2.9	-118.9	-121.9
No	1	-33.4	-0.8	-34.1	-10.5	-85.9	-96.4
No	4	-19.5	-2.5	-22.0	29.8	-150.7	-120.9

*Discount rate is 7%

Table 11. Total Changes in Welfare if Citrus Canker Became Established

Quarantine	Supply Elasticity	Total Welfare - California			Total Welfare - U.S.		
		Total	95%	99%	Total	95%	99%
		- - - - - - - - - - - - -	($mil)	- - - - -	- - - - -	- - - - -	- - - - -
Yes	1	-890.1	-845.6	-881.2	-5,775.2	-5,486.4	-5,717.4
Yes	4	-525.6	-499.3	-520.3	-5,375.6	-5,106.9	-5,321.9
No	1	-280.7	-266.7	-277.9	-968.3	-919.8	-958.6
No	4	-173.2	-164.5	-171.4	-1,008.9	-958.4	-998.8

Table 12. Cost of Eradication Compared to Establishment of Citrus Canker

		California Alone		All of U.S.	
		Total	Total	Total	Total
Probability Of Success		95%	99%	95%	99%
Costs (of Eradication)		- - - - ($mil)	- - - - -	- - - - - ($mil)	- - - - -
Small		1.6	1.9	3.6	4.0
Large		81.1	82.1	293.0	294.8
Benefits (Cost of Establishment)					
Quarantine	Long-run Elasticity of Supply	95%	99%	95%	99%
		($mil)	($mil)	($mil)	($mil)
yes	1	845.6	881.2	5,486.4	5,717.4
yes	4	499.3	520.3	5,106.9	5,321.9
no	1	266.7	277.9	919.8	958.6
no	4	164.5	171.4	958.4	998.8