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The Economic Consequences of Pierce's Disease and Related Policy in the California Winegrape Industry

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ABSTRACT. Since 2000, the California Department of Food and Agriculture (CDFA), has spent approximately $40 million per year to contain and control the Glassy Winged Sharpshooter (GWSS), which spreads Pierce's Disease (PD). Compliance with the program has cost the nursery industry approximately $7 million per year in recent years. Using a simulation model of the market for California winegrapes, we estimate PD costs winegrape growers and consumers $61 million annually, with the current program in place. If the PD Control Program ended, and the GWSS was distributed freely throughout California, the annual cost to the winegrape industry would increase by $261 million.

Key Words: Pierce's Disease Control Program, exotic pest, simulation model, perennial crop model, California wine and winegrapes

JEL codes: C61 **(**Optimization Techniques; Programming Models; Dynamic Analysis), Q11 (Aggregate Supply and Demand Analysis; Prices), Q13 (Agricultural Markets and Marketing; Cooperatives; Agribusiness), Q18 (Agricultural Policy; Food Policy)

1. Introduction

Pierce's Disease (PD) is a disease of grape vines that is caused by a strain of the bacterium *Xylella fastidiosa (Xf)*. The disease is endemic to California. It has many host plant species, and is spread by several species of insects called sharpshooters. PD can kill grapevines quickly and, as yet, scientists have not developed an effective cure or preventive measure. PD represents a significant threat to an industry that contributed $3.0 billion to the value of California's farm production (including $0.9 billion in table grapes and raisins and $2.1 billion in winegrapes) in 2010, and much more in terms of total value added (United States Department of Agriculture/National Agricultural Statistics Service, 2011).

The main native vector of the disease is the Blue-Green Sharpshooter (BGSS), which imposes chronic but usually manageable losses in the high-value Napa Valley and North Coast areas, and has done so for at least a century. Major concerns about PD grew after a devastating outbreak in the Temecula Valley (in southern California) in the late 1990s, spread by the newly arrived, non-native Glassy-Winged Sharpshooter (GWSS). Compared with the BGSS and other native sharpshooters, the GWSS can fly farther and feed on a greater variety of plants and plant parts, and consequently has a much greater capacity to spread PD.

Spurred by concern over this new vector's ability to spread PD, the California Department of Food and Agriculture (CDFA) developed an extensive program (the Pierce's Disease Control Program, or PDCP)—that includes funding for research, area-wide controls, and inspections—that focuses on preventing the spread of the GWSS from south to north, in particular to the Napa Valley, where the GWSS is not yet established. The control program requires nurseries, at their own expense, to treat all plant stock being shipped northward, including ornamental species for urban areas. It also provides for inspections of those shipments both at the source and at the final destination in some cases, and maintaining GWSS traps in winegrowing regions statewide (California Department of Agriculture, 2010). Public funds are spent to prevent the spread of the GWSS from citrus orchards to nearby vineyards in the Temecula Valley by offering insecticide treatments to citrus growers free of charge.

Using cost accounting procedures, Tumber et al. (2012) estimated that, in recent years, PD has cost approximately $110 million per year. This total comprises approximately $50 million per year spent on preventive measures, including $10 million incurred by the nursery industry in costs of compliance as well as expenditure of about $40 million under the PD/GWSS program, and $59 million per year in the value of vines lost and income forgone by winegrape growers, even while the GWSS is being held in check by these programs.

Funding for the PD/GWSS program is currently threatened by competing demands for state and federal funds, but little is known about the economic implications of changing or ending the program. This paper addresses the question: What would be the economic consequences in the California winegrape industry if the PD Control Program were to end? Or, equivalently, what are the expected benefits from continuing the present program? To address this question, we developed a dynamic simulation model of supply and demand for California winegrapes. We report results from using that model to evaluate the aggregate impact of the disease, and the benefits from the current control programs versus a no-program alternative, over a range of scenarios for pest and disease prevalence. Our simulation results using most likely parameter values indicate that Pierce's Disease currently costs the winegrape industry approximately $61 million per year, and would cost an additional $261 million per year if the PD Control Program were halted. When we include costs borne by the table grape and raisin grape industries, we estimate that the disease currently imposes costs of $87 million per year on growers and consumers and would cost an additional $358 million per year without the PD Control Program.

2. Model Overview

The model presented in this paper is a dynamic simulation of supply and demand for California winegrapes. Each of six regions produces one of three regionally defined quality classes of winegrapes ("High", "Medium", or "Low"). Regions are linked on the demand side either because they produce the same quality (perfect substitutes) or through cross-price elasticities of demand. Supply shocks, such as disease outbreaks or the availability of better pesticides, can affect either individual regions or the state as a whole, depending on the nature of the shock, but the supply regions are otherwise unrelated. The demand side of the model is parameterized based on estimates developed by Fuller and Alston (2012) for this purpose. The supply side of the model is the main focus of the work in this paper, including the representation of responses to prices, the nature of pest and disease prevalence, and market closure conditions.

The perennial nature of grapevines suggests a dynamic model is necessary to capture the essential character of supply response. After planting, grapevines take several years to mature and then can remain economically productive for decades (typically 20–25 years, but often longer). Thus, decisions regarding their planting and care can have effects that linger long into the future. This aspect is particularly relevant when considering the impact of a disease that destroys productive capital by killing healthy, mature vines, such that it takes time to replace lost vines and for production to recover—a multi-period effect. We do not model explicitly the spatial dynamics of sharpshooter populations, but we do model the dynamics of vineyard age structure and production responses to PD losses, prices, and management strategies.

The equations of the model are specified as linear forms and are parameterized using data on initial values of prices, quantities, and acreage, combined with assumptions about underlying trends in demand and yield, and elasticities[1]. The model starting points for prices, quantities, and acreage are the average actual values calculated from NASS/CDFA Crush and Acreage Reports for the years 2008–2010 (California Department of Food and Agriculture/National Agricultural Statistics Service 2009-2011). These starting values do not vary across alternative simulations. In recognition of uncertainty about values for some other key parameters, alternative values are considered in order to examine the implications for findings, and we present sensitivity analysis and discussion of the robustness of the results to changes in key parameter values.[2]

Previous work has revealed that it is difficult to estimate useful elasticities of supply or demand for agricultural products, and the estimates are often imprecise and fragile. Estimation challenges are more pronounced on the supply side, especially because of dynamic responses that imply lags between observed price changes and their realized impacts, such that it is often necessary to model decision-making under uncertainty and the formation of unobserved expectations. These aspects are particularly pronounced for perennial crops where the production cycle is multi-year and the dynamics are long term (Gray et al. 2005).

Recognition of the limitations of econometric estimation in agricultural policy modeling has led to an increasing use of calibration techniques, and expert opinion and assessments based on specific knowledge of the industry, to avoid undue reliance on econometrically estimated

[1] The econometric analysis of Fuller and Alston (2012) provides some information about demand elasticities, but comparably useful estimates are not available for the supply side. Even when econometric estimates are available, to define the structure of the model and likely values for its parameters, it is necessary to use considerable judgment—based on theory and knowledge of the industry, its markets, and technology—to augment and filter the limited amount of information that can be gleaned from econometric analysis.

[2] Further details of the parameterization of the model can be found in Fuller (2012).

elasticities.[3] Such an approach is particularly appropriate for an analysis that proposes to evaluate effects of policy and other changes that imply corresponding effects in markets outside the range of historical experience or where estimates of long-run responses are desired, since typical elasticity estimates from econometric models are most likely to reflect only short- or intermediate-run responses (Gray et al. 2005). These observations are especially pertinent for the present context, as the model presented in this paper is used to simulate future responses, over a comparatively long period of time, to policy changes that can be regarded as fully anticipated and permanent in nature. To evaluate this kind of policy change requires a measure of long-run responses of the type that generally cannot be estimated directly, especially for perennial crops. Moreover, our goal is to simulate a policy change that goes outside the range of past policy changes. In addition, it cannot be argued that the structure of supply and demand for winegrapes will be stable over the time period being simulated or that the market has been in long-run equilibrium over the recent past.

2. The Supply of Winegrapes in California

This section discusses the details of the regional structure of the model and then develops the equations for supply response in a representative region. In subsequent sections the supply and demand sides are linked through market clearing conditions.

Regional Aggregation

Regional disaggregation is appropriate in view of very significant variation in production methods, PD incidence, and prices of grapes produced among regions. The insects that vector the disease, the effective disease incidence, and control measures, vary greatly across the state.

[3] Calibration approaches to modeling supply response are discussed and illustrated by, for example, Howitt (1995), Ahmed, Hertel, and Lubowski (2008), Mérel and Bucharam (2010), and Howitt et al. (2012).

In the Napa and Sonoma Valleys, the main vector (the BGSS) has a strong preference for lush, new growth. Here there are few, if any, effective pesticides for controlling the vector. In some cases growers can revegetate riparian areas with plants that do not attract the insect; and in other cases, where prevalence is high, land is abandoned (Fuller et al., 2011). In southern California, the main vector (the GWSS) is a non-native, long-distance flyer that can eat many different parts of the grapevine (among hundreds of other plant species and subspecies). Here, because of soil types and temperatures, as well as insect behavior, systemic insecticides are very effective in keeping sharpshooter populations low. All other parts of California face much lower, if any, Pierce's Disease pressure, although in some cases large-scale prevention measures may be keeping sharpshooter populations at the current (very low) levels.

Grape crush prices and yield also vary significantly. In the Napa and Sonoma Valleys, vineyards typically produce very few tons per acre under very carefully controlled conditions. In the Central Valley, production styles are very different; vineyards can produce ten times the quantity per acre as those in Napa; prices are lower, and much more bulk production takes place (California Department of Food and Agriculture/National Agricultural Statistics Service, 1981–2011). The rest of the state produces a range of winegrapes that fall between these two extremes in terms of price and yield. Prices and yields also vary significantly among varieties within regions (among varieties of the same color as well as between red and white winegrape varieties) but for the purposes of this analysis all varieties are aggregated within each of the six production regions, which are defined as aggregates of crush districts on the basis of the volume-weighted average price per ton of grapes produced as well as the incidence and epidemiology of Pierce's Disease. Table 1 presents regional summary statistics on yields, prices, and production.

[Table 1: Production Regions – Definitions and Basic Statistics]

Investment and Output Response

Models of supply response for perennial crops are reviewed in detail by Gray et al. (2005). The theoretically more-defensible models partition the supply response into separate equations representing elements of yield per bearing acre and the number of bearing acres (or other measures of the stock of bearing vines) with adjustments to bearing acreage reflecting planting and removal of vines with a lag to reflect the time it takes for vines to come into production. Based on knowledge of the winegrape industry and the literature, in this paper we assume that the only supply response to price changes in this analysis is through plantings (i.e., with no yield response to price, and removals based simply on the age of vines and random vine death). Given the relatively modest range of economic changes being analyzed, removal response to changes in price induced by the policy seems unlikely because the resulting price changes are so small. Most studies of perennial crop supply response do not allow for removals or yields to respond to prices. Studies that do allow for these responses rarely find evidence of much response (Gray et al., 2005).

Our model includes an assumption that all vines are removed at age 25, either for replacement with new vineyard or for replacement with some other crop. The equations for the evolving age structure of planted acreage in the model explicitly reflect these removals. Vines in this model do not bear grapes until they are three years old, do not bear at their maximum yield until they are either five or six years old, and are assumed to be removed after the harvest in their 25th year, consistent with typical practice in California winegrape production.

Some studies have argued for a modeling approach based on neoclassical investment theory, and this paper has adopted an approach based on that argument combined with elements of rational expectations to model investments in new plantings, in an adaptation of the approach developed by Gray et al. (2005).[4] The model is applied separately in each of six distinct winegrape producing regions, which are treated as independent on the supply side but related through competition on the demand side of the market. The development that follows next refers to one representative region. Fuller (2012) provides details on model parameter values, interpretation, and sources.

An investment in an acre of new plantings will generate a stream of variable profits—revenue minus operating costs—over the life of the investment. Mathematically,

(1) $$PV_t = \sum_{n=0}^{T} \pi_{t+n} \left(1+r\right)^{-n},$$

where PV_t is the present value in time t of the stream of net revenue generated by the investment in an acre of vines planted in time t; π_{t+n} is the net return that will accrue to the newly planted vineyard in the year $t+n$—i.e., n years in the future; and r is the real discount rate. T is the lifespan of the vineyard investment. The stream of annual net returns (or variable profits) depends on yields (Y tons per acre), the output price (P dollars per ton), and variable costs (VC dollars per acre), according to:

(2) $$\pi_{t+n} = P_{t+n} Y_{t+n} - VC_{t+n}.$$

In this equation, Y_{t+n} is the yield of an acre of vines planted in year t that will be n years old n years hence. In the analysis of California winegrape production, the output price and yields are expected to vary over time, and some of that variation is predictable. The expected yields from the newly planted vines will vary in predictable ways as the vines age, and the output price will vary in response to shifts in supply and demand, some of which are foreseeable based on information that is currently available (the current stock of bearing and nonbearing vines, for

[4] See Akiyama and Trivedi (1987) and Dorfman and Heien (1989) as reviewed by Gray et al. (2005) for a discussion of modeling approaches based on neoclassical investment theory.

instance). Variable costs per acre are treated as constant and exogenous in real terms for an individual producer, and constant region-wide for a given total acreage, but in the Napa-Sonoma and Southern San Joaquin regions variable costs are also an increasing function of the total region-wide vineyard acreage, reflecting the effects of upwards sloping supply of specialized inputs (in particular, high-quality land) to the winegrape industry in those regions.

The behavioral model presented here is one of a representative firm that can be used to capture the region-specific supply response, taking account of the effects of planting decisions on both the cost of new plantings and on the future time path of output, prices, and variable costs. Assuming rational expectations, as described below, the time *t* expectation of net revenue in time *t*+*n* can be written as Equation (3). In this analysis, it is assumed that the variable costs per acre are constant in real terms, whereas the output price and yields will be expected to vary.

(3) $$E_t\left(\pi_{t+n}\right) = E_t\left(P_{t+n}Y_{t+n}\right) - VC_{t+n}.$$

The investment decision involves comparing the expected present value of the stream of net income with the cost of the new plantings, C_t = C(PL_t), which includes the cost of the planting material and the cost of the labor and capital and other inputs used to prepare the land for planting and to plant the vines, as well as the rental cost of the land for the life of the investment. Thus producers choose the quantity of new plantings in the current period, *t*, to maximize

(4) $$E_t\left(NPV_t\right) = E_t\left(PV_t\right) \times PL_t - C_t,$$

where PV_t is the present value of the stream of net income per acre of new plantings. In forming expectations about prices and variable costs, producers have to anticipate production and prices over the life of the investment, which depend on future plantings as well as the current stock of vines and the current planting decision. Thus it is a complex dynamic problem. We propose a type of rational expectations mechanism, following Gray et al. (2005) to solve it; Fuller (2012) provides further detail.

Yield

The formation of expectations of the net present value of investment in new plantings uses information on the yield-age profile of vines, which can be treated as not varying in general shape over time, and the underlying trend in yield per acre of mature vines, reflecting the influence of management and technological change (in reality yields also reflect random seasonal variation in weather and pests that average out in this model that emphasizes long-term investment responses). To capture these characteristics, we assume the expected yield of mature vines can be written as a trend model of the following form:

(5) $$YM_{t+n} = YM_t + gn,$$

where YM_{t+n} is the projected yield per mature bearing acre in year $t+n$, which is equal to the value in the base year, YM_t, scaled by a linear growth rate g. The trend growth rates and implied yield values in year 50 were calibrated based on a combination of analysis of historical data, responses to a questionnaire sent to a group of winegrape growers, academics, and industry experts, and some consultation within this group (see Fuller, 2012 for details).

The average yield per acre in year t, Y_t is also affected by the age structure of the population of mature and immature bearing vines. The formation of expectations of the net present value of investment in new plantings uses information on the yield-age profile of vines, which can be treated as not varying in general shape over time. That is,

(6) $$Y_{i,t+n} = y_i YM_{t+n},$$

where y_i is the yield of an acre of vines aged i years as a fraction of the yield of an acre of mature bearing vines.

Investment cost (C_t), is assumed to be a cubic function of the rate of new plantings (PL_t). Mathematically, this can be written as

(7a) $$C_t = c_1 PL_t + c_2 PL_t^3.$$

Hence, the equations for the average and marginal cost of investment are

(7b) $$AC_t = c_1 + c_2 PL_t^2; \text{ and}$$

(7c) $$MC_t = c_1 + 3c_2 PL_t^2.$$

The values of the parameters of the total, average, and marginal cost functions (c_1 and c_2) are derived based on assumptions about the elasticity of supply of new investment (reflecting upwards sloping supply of planting materials from the nursery industry and other variable inputs, perhaps also including venture capital, in the short run) combined with information from cost and return studies prepared by University of California Cooperative Extension (UCCE) staff since 2000 on investment costs for winegrapes (University of California Cooperative Extension, 2000–2011), and plantings information derived from Acreage Reports (California Department of Food and Agriculture/National Agricultural Statistics Service, 1981–2011).

Because we could not accurately measure the marginal cost (or price) a priori, the parameters of the plantings cost function were calibrated using alternative assumptions about the flexibility of the average cost of new plantings with respect to the quantity of new plantings ($\varphi_{AC} = d\ln AC/d\ln PL$) as follows:

(8) $$c_2 = \frac{\partial AC}{\partial PL}\frac{1}{2PL_0} = \varphi_{AC}\frac{AC_0}{2PL_0^2},$$

where AC_0 is the initial average cost, and PL_0 is the initial value for new plantings.[5] The following formula can be used to solve for parameter c_1:

(9) $$c_1 = AC_0\left(1-\varphi_{AC}\right).$$

Then the (non-negative) quantity of new plantings in time *t*, chosen to maximize the expected net present value of the investment, will be the quantity of plantings such that expected present value of net returns will be equal to the marginal cost of the new plantings (per acre). That is, the first-order necessary condition for a maximum is that marginal benefit (per acre) of new plantings equals marginal cost:

(10) $$E_t\left(PV_t\right) = MC_t \ .$$

In these equations, plantings decisions are based on expectations of prices and yields into the distant future. They also depend on the expected total acreage in a given year since it is assumed that variable costs depend on total planted acreage within a region. Inherent in these expectations is knowledge not only of the parameters on the supply side of the model—including yield relationships and the dynamics of the stock of bearing vines as well as the determinants of plantings represented in Equation (10)—but also knowledge of the parameters on the demand side. It is not practicable to solve the specific structure of this model analytically for the supply-response model implied by rational expectations. Instead, we use an iterative numerical simulation process, described in section 3.

Bearing Acreage

Vineyard acreage evolves according to

[5] Values of φ_{AC} = 1/1.5 and 1/4 are used for the Southern San Joaquin and Napa-Sonoma regions, respectively; φ_{AC} = 1/2 in all other regions.

$$(11)\qquad A_{i,t} = \begin{cases} PL_t \text{ for } i = 0, \\ A_{i-1,t-1} \text{ for } 1 \le i \le 25, \\ 0 \text{ for } i > 25. \end{cases}$$

where $A_{i,t}$ is the acreage of vineyard aged *i* years in year *t*. After 25 years the acreage is retired or replanted. After an acre is planted, vines within that acre are lost to death from non-PD causes, at a proportional rate δ_0, and from Pierce's Disease, at a proportional rate δ_1. We assume these vines are replanted every year except for vines aged 23 years or older, since any replacements of these vines will not produce grapes before the entire block is removed. Hence, in each year, the area of vines replanted, RP_t, is:

$$(12)\qquad RP_t = (\delta_0 + \delta_1)\sum_{i=0}^{22} A_{i,t}.$$

The per-acre cost for these replacement vines is assumed to be a cubic function of the rate of replacements, as it was for new plantings. Mathematically this can be written:

$$(13)\qquad RC_t = \mathrm{c}_3 RP_t + \tfrac{1}{2}\mathrm{c}_4 RP_t^2.$$

The values of the parameters of the replacement cost function (c_3 and c_4) are also derived based on information from cost and return studies prepared by the UCCE on average costs (University of California Cooperative Extension, 2000–2011), CDFA/NASS Acreage Reports (California Department of Food and Agriculture/National Agricultural Statistics Service, 1981–2011), and assumptions about how average cost changes with changes in vine replacements.

Production

Production is simply the product of the age-specific yield per acre from Equation (6) and the number of acres from Equation (11), summed across age categories:

(14) $$Q_{t+n} = \sum_{i=4}^{24} Y_{i,t+n} A_{i,t+n}$$

Variable Cost

The specification of the investment cost function as a cubic form limits the supply response to price in the short run. Supply response to price at the industry level is further constrained by limits on the supply of suitable land, an aspect that is reflected by specifying the variable cost per acre as an increasing function of the total acreage of vineyard within a region. The variable costs also depend on the prevalence of disease in the region, which causes growers in some regions—Napa-Sonoma, the Southern San Joaquin Valley, and Southern California—to spend resources on preventive measures; d_r is a dummy variable that equals one if r is one of these three regions, and zero if not:

(15) $$VC_{t+n} = \mathrm{v}_0 + \mathrm{v}_1 \sum_{i=0}^{25} A_{i,t+n} + \mathrm{v}_2 d_r$$

This equation is parameterized based on prior views about the long-run supply elasticity of vineyard land, regional acreage from Acreage Reports, and knowledge of the relationship between the sharpshooter population and the incidence of Pierce's Disease, gleaned from grower interviews and the history of Pierce's Disease throughout the State (California Department of Food and Agriculture/National Agricultural Statistics Service, 1981–2011; Fuller, 2012).

3. Demand for Winegrapes in California and Model Closure

The model is closed by equating annual demand with annual supply for each of three qualities of winegrapes. Because of the large number of variables, constraints, and the annual nature of the desired output, it was not feasible to solve this specific structure analytically for the supply-response model implied by rational expectations. Instead, we used numerical simulation methods to solve the model. Specifically, we used the GAMS CONOPT solver—which is a nonlinear programming method that uses a generalized reduced gradient (GRG) algorithm based on the work of Abadie and Carpentier (1969)—to calculate prices, production, and PD damages over 50 years, 2011 to 2060.[6]

Demand for California Winegrapes

Annual demand consists of three regional markets, represented by a system of linear inverse demand equations, specified as follows, where *j* represents the six supply regions, (see Table 1 for descriptions of the regions).

$$
(16)\quad
\begin{aligned}
P_{Low,t} &= \left(\phi_0^{Low} - \sum_j \phi_j^{Low} Q_{j,t}\right)\left(1 + \beta^{Low}\right)^t \\
P_{Med,t} &= \left(\phi_0^{Med} - \sum_j \phi_j^{Med} Q_{j,t}\right)\left(1 + \beta^{Med}\right)^t \\
P_{High,t} &= \left(\phi_0^{High} - \sum_j \phi_j^{High} Q_{j,t}\right)\left(1 + \beta^{High}\right)^t
\end{aligned}
$$

Values for the slope and intercept parameters for each of these equations are calculated using (a) the 2008–2010 three-year average values of prices and quantity for each region, based on data from the CDFA/NASS Crush Reports, combined with (b) estimates of price flexibilities, derived from the econometric and "synthetic" estimates described in Fuller and Alston (2012) as well as judgment based on knowledge of the winegrape industry and other agricultural industries. Values for the growth rate parameters (b^i in Equation 16) were chosen to reflect underlying growth rates in demand (reflecting the influence of growth in population, per capita income, other demographic variables, and other trend factors such as prices of other goods and

[6] Vineyard acreage was calculated over 75 years, since plantings in year 2060 (the last year of the 50-year horizon) depend on expected returns over the subsequent 25 years (2061 through 2085) and thus the 50-year planning horizon entails projections over 75 years; solutions are found for the first 50 years and then the values are projected for the 50th year forward for the next 25 years as though a steady-state solution had been reached in year 50.

preferences). Initial values for these were set at one percent per annum in each case in view of past trends in prices.

Market-clearing prices are derived by substituting for Q_t from Equation (14)—which depends on the acreage from Equation (11) and realization of the yields from Equations (5) and (6)—into the system of demand equations in (16). The resulting prices are used in a recursive model solution procedure, described next.

Model Solution Procedure

The model solution procedure follows an iterative recursive process for a given policy scenario. First, a set of starting values is chosen for the stream of expected prices and total acreage to derive the net present values per acre. The set of starting values implies a stream of plantings over the 50-year planning horizon of 2011–2060. Then, using that stream of plantings and other factors, the stream of bearing acreage is projected over the next 25 years for a total of 75 years of projected values for variables. The product of the stream of projected acreage with the stream of expected yields per acre, is the corresponding stream of expected production, which is substituted into the price dependent demand system to compute the implied market-clearing prices. Next, these solutions replace the starting values for expected prices and total acreage and the process is repeated. The process is iterated until the expected prices do not change appreciably—that is, the stream of expected prices used to generate the stream of plantings is equivalent to the stream of prices implied by the stream of plantings. It is in this sense that the model entails rational expectations.

Model Validation

Several steps were taken to check the validity of the model and its ability to predict winegrape market behavior over a 25- or 50-year horizon. Using the baseline parameters, the model was used to simulate production quantities, acreage, prices, and the resulting profits, consumer surplus, and net benefits over the 50-year time horizon, 2011–2060. Relevant experts were asked to review these predictions and comment on them, as a check on whether the model as specified yielded plausible predictions. After making adjustments to the model so that the predictions were more-nearly in line with the expert opinions, as a further check on the model, the implied supply elasticities were calculated, by running parametric simulations. Cross-price elasticities are very near to zero over all time horizons. Long-run (30-year) own-price elasticities of region-specific supply are all between 0.5 and 0.6.

Price, Quantity, and Economic-Welfare Impacts

Under each alternative scenario, producer benefits were computed for each year of the simulation as the change in profit or producer surplus (computed as an element of the model solution procedure) compared with the baseline scenario. Annual consumer benefits were computed as changes in Marshallian consumer surplus (the area behind each demand curve above the intersection of supply and demand), reflecting the effects of both price changes and shifts in demand. Annual total benefits are equal to the sum of producer and consumer benefits. In the sections that follow, we provide detailed model results under the baseline and alternative scenarios.

4. Policy Simulations: Scenarios

Policy simulations were conducted using this model and a range of assumptions about scenarios regarding potential cuts to program funding, PD prevalence, and a case in which the disease simply ceases to exist. Much is unknown about the future of Pierce's Disease and the programs in place to keep it in check. Potential changes to disease pressure may occur because of climate change, new vectors or movement of existing vectors to new locations, different cropping patterns, changes in technology, urbanization, or changes in government programs. Alterations to the PD programs may occur because of budget shortages, competition from other pests and diseases for policy resources, changes to administration, or other reasons.

To make more confident predictions of likely pest and disease prevalence and industry growth under alternative scenarios, industry experts were consulted. Expert opinions on the potential future of disease incidence along with winegrape production were elicited in both informal consultations and through the use of a questionnaire that was sent to various experts, including winegrape growers, academics, and farm advisors. Further information on the questionnaire is available in Fuller (2012).

Baseline

The "Baseline" scenario represents the economic outcomes given the incidence of the disease with current programs, technology, and mitigation practices. Under this scenario, the myriad of CDFA-, USDA-, and locally funded Pierce's Disease boards, task forces, monitoring and control programs, remain in place for the 75-year period.

Silver Bullet

The best possible (although extremely unlikely) outcome of the PD research program would be a costless cure for Pierce's Disease, or "Silver Bullet" scenario. The death rate of vines is simply reduced in the model to what it would be in the absence of PD, and corresponding adjustments are made to costs to reflect the lack of PD mitigation costs. This "Silver Bullet" scenario allows the estimation of the total cost of the disease, comparing scenarios with and without the disease, leaving all other economic relationships unchanged. After calculating economic welfare for the baseline case and then the "Silver Bullet" scenario, the difference can be interpreted as the cost (or benefit) of Pierce's Disease, as borne by winegrape producers and consumers under current policies and technology.[7]

Statewide Outbreak

The worst potential scenario would be a statewide "outbreak"—a scenario in which the GWSS is free to move and becomes established throughout California. It is possible that this could eventually occur even with the current programs in place, and many believe that GWSS would almost certainly become endemic throughout California if the control programs ended. It could take a long time for the full consequences from ending the program to be realized. In the questionnaire respondents were asked what would happen, in terms of the eventual equilibrium distribution of annual losses of vines from PD, if the PD Control Program ended. Based on the survey responses, in the model it takes 10 years before the full effect (larger rates of vine losses) from a widespread outbreak is felt. An exponential function for PD deaths was applied between baseline incidence and the full disease incidence.

Regional Outbreaks

Alternative outbreak scenarios, in which GWSS becomes endemic in particular regions in isolation, are also possible. If the pesticides used in Southern California stopped working as effectively or became less frequently used, GWSS and PD prevalence could increase in that region alone. Alternatively, if programs aimed at limiting the spread of GWSS from Southern California were eliminated or cut back, it is possible that the adjacent region, the Southern San Joaquin Valley, could experience outbreak rates of PD losses. The biggest fear, however, is that

[7] Our analysis of the "Silver Bullet" scenario does not take into account potentially negative economic impacts that a costless cure for Pierce's Disease could have on grape producers in California. If such a cure were found, large-scale grape production might become possible in other parts of the country that currently cannot produce grapes because of high PD incidence and a lack of effective prevention tools. Increased production, all else equal, would bring grape prices down, which would negatively affect California winegrape growers. Therefore, for the purposes of this analysis, it is assumed that the "Silver Bullet" is a California-specific cure.

the GWSS could migrate into the Napa and Sonoma Valleys, and become established in that high-value region in addition to the BGSS vector that is already a problem there. The regional outbreak scenarios use baseline PD incidence rates for all regions except the one with the outbreak, for which PD incidence is set to the corresponding "outbreak" rates (which are also used together to represent a statewide outbreak rate).

5. Policy Simulations: Results

Table 2 shows changes in welfare under the various scenarios described in the previous section, relative to the baseline case. These changes are the averages of the annual welfare changes over 50 years, 2011 to 2061. These were computed by averaging the (non-discounted) welfare measures over the 50-year horizon, to provide estimates that are more easily and intuitively compared to other annual measures such as program expenditures and value of production.

The measured welfare changes throughout this paper represent changes in producer and consumer surplus for producers and consumers of winegrapes. They do not include the costs of government expenditure (effectively borne by taxpayers) or costs (or benefits) to the citrus industry or nursery industry associated with the current PD control program and compliance with it. The first six columns in Table 2 present regional effects, and the rightmost column shows the statewide sum. The "net benefit" within a region should not be interpreted as a measure of net benefits to that region but rather is a measure of net benefits to producers and consumers (or buyers) of the winegrapes from that region, where most of the consumer benefits are accruing to final consumers in other geographical locations.

The first section of Table 2 reports results from the "Silver Bullet" scenario as compared to the baseline. The difference between the two sets of economic welfare measures can be thought of as a measure of the costs of the disease to producers and consumers given current programs. The results for the "Silver Bullet" case suggest that the disease costs producers and consumers of California winegrapes over $55 million per year, more than half of which ($31 million) is borne by producers in California, roughly 1.4 percent of winegrape cash income in recent years (California Department of Food and Agriculture, 2011).[8]

In the statewide outbreak scenario, compared to the baseline, the State as a whole is projected to lose over $265 million annually, including a loss to producers of $161 million per year, or 7.2 percent of winegrape cash income in recent years. This total effect reflects the net effects of benefits to growers in the Coastal region, the Northern San Joaquin Valley and Northern California, where PD costs would be comparatively minor and more than offset by the benefits of higher prices resulting from the heavier losses in the primary production areas. For similar reasons, producers in the Northern San Joaquin Valley and Northern California experience losses in the "Silver Bullet" scenario.

The statewide annual cost of regional outbreaks compared to the baseline is $136 million for the case of Napa-Sonoma, $51 million for the case of the Southern San Joaquin Valley, and $64 million for the case of Southern California. Projected losses are very dire for some regions, in particular Napa-Sonoma, and Southern California, both of which experience drastic increases in PD in this scenario. Regional outbreaks benefit producers in the regions that are not affected directly, because of price increases resulting from a lower total statewide grape crush. A Napa-Sonoma-only outbreak, for example, would benefit all producers except those in the Napa-

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[8] As noted, this measure does not include the costs of the PD program, borne by government and industry, but not reflected in the market for winegrapes.

Sonoma region. However, for each of those other regions the corresponding losses to consumers resulting from increased prices more than offset the producer gains. The statewide effects for producers, consumers, and their combined sum are all negative.

[Table 2: *Average Annual Costs of PD and Ending the PD Control Program under Alternative Outbreak Scenarios, Relative to Baseline*]

While table grapes and raisin grapes were not included explicitly in the model, those industries would be affected in some of our scenarios, so we computed "back-of-the envelope" estimates of welfare effects on those markets. Table grapes and raisin grapes are both grown almost exclusively in the Southern San Joaquin Valley, and we assumed that the direct impacts in those industries would be in proportion to the direct impacts in the winegrape industry in the same region.

To estimate those direct impacts on the winegrape industry in the Southern San Joaquin Valley we ran the model under the respective scenarios isolating that section of the State on the demand side, assuming that there would not be any cross-price effects from winegrapes on the table or raisin grape markets. We then computed the total effect (T) of the respective scenarios as

(17) $T = (1+k)W$,

where W represents the total welfare effect of the scenario in question on the winegrape industry in the Southern San Joaquin Valley, and $k = 2.11$ is the ratio of the total farm value of table grape and raisin grape production to the total value of winegrape production in the region, averaged over the years 1995–2010. Including effects on table grapes and raisin grapes adds another $14 million to the current annual cost of the disease and $109 million to the annual cost in the statewide outbreak scenario that would apply if the control programs were to be halted.

Because the sum of the change from "Silver Bullet" to "Baseline" and "Baseline" to "Outbreak" is equivalent to the difference between "Silver Bullet" and "Outbreak," the welfare effects of alternative scenarios as compared to a no-PD scenario can be computed. As such, relative to a scenario without PD, the full cost of a statewide outbreak could be upwards of $322 million annually for winegrapes alone, and another $123 million annually for table and raisin grapes.

Sensitivity Analysis

Because much is unknown about current and potential incidence of PD, sensitivity analyses were conducted to examine the range of economic impacts of the disease implied by the range of plausible rates of incidence as indicated by the responses to the survey questionnaire. The sensitivity analysis was conducted by applying the full range of questionnaire responses on rates of incidence to parameterize scenarios for current PD losses as well as potential losses if the program were to be abolished.

Table 3 compares average annual changes in total welfare over the 50-year program for the statewide "Outbreak" scenario as well as the "Silver Bullet," compared with the "Baseline" scenario using three alternative parameterizations of the "Baseline" scenario ("Low," "High," or "Best-Guess" rates of losses to Pierce's Disease). "High" indicates the maximum value for baseline Pierce's Disease losses from the survey responses, and "Low" represents the minimum. The relatively modest range of baseline current rates of losses to PD implies substantial differences in estimated welfare impacts. The net welfare effect for California as a whole ranges from $11 million to $123 million per year for winegrapes alone. Each measure varies by more than a factor of 10, which is quite substantial and highlights the importance of good parameter estimates, and the difficulties of making confident precise statements about costs. The remainder of Table 3 compares a statewide outbreak to the range of Pierce's Disease baselines. The estimated average annual cost of a statewide outbreak for winegrapes ranges between $219 million and $311 million.

[Table 3: *Average Annual Costs of PD and Ending the PD Control Program, Relative to Alternative Baseline Parameterizations*]

Further analysis was conducted to explore the sensitivity of the estimates of the cost of ending the program to assumptions about PD prevalence. Responses varied widely regarding what could happen if the PD program were to end, making it difficult to decide what values should be used to parameterize the outbreak cases. Sensitivity analysis was conducted over the range of responses regarding PD prevalence if the control program were ended, as represented by the statewide outbreak scenario. Using the range of PD losses suggested in surveys for the outbreak scenario to parameterize the model (see results labeled "Low Outbreak" and "High Outbreak" in Table 4), producers would lose between $107 and $880 million. Figure 1 summarizes the same information graphically.

[Table 4: *Average Annual Costs of Ending the PD Control Program under Alternative Outbreak Scenarios, Relative to "Best Guess" Baseline*]

6. Conclusion

Tumber et al. (2012) estimated costs of the current Pierce's Disease program borne by taxpayers, citrus producers, and plant nurseries as well as the costs to the wine industry from lost production and costs of replacing vines lost to the disease under the existing program. The simulations and associated welfare calculations presented in this paper build on that work and provide a more complete set of measures of the total costs of PD as borne by the winegrape industry, with or without the PD program, and the economic incidence between winegrape consumers and producers, region by region.

The results of these simulations suggest that programs in place to curb Pierce's Disease yield a substantial net economic benefit. All of the questionnaire respondents stated that they felt PD incidence would increase if the programs were halted, and the simulation results suggest that the annual economic benefit from the program remaining in place is greater than the costs of running the program: the program currently costs approximately $50 million per year (Tumber et al. 2012), while the annual cost of the "most likely" outbreak scenario resulting from cessation of the PD program is more than five times that amount for the winegrape industry alone (i.e., $267 million per year as shown in Table 2)—a benefit-cost ratio of roughly 5:1. The savings and benefit-cost ratio are large even though (a) the yearly average of benefits from the program includes the first 10 years in which losses from PD incidence are building to outbreak rates but have not yet reached them, (b) in some less-affected regions, producers may in fact be better off in the outbreak scenario because of increased prices brought about by disease-induced reductions in supply from more-affected regions.

The sensitivity analysis suggests that the program yields net benefits, even under the most conservative estimates of incidence of Pierce's Disease if the program were to end. Using the "Low" rates of annual losses to PD, the annual cost to the winegrape industry from eliminating the program would be $107.4 million (see Table 4), a benefit-cost ratio of greater than 2:1. Using the high end of responses regarding potential PD if program funding were cut, the program is estimated to yield annual net benefits of up to $800 million compared with a scenario where the program does not exist, even after the $50 million program expenditure is taken into account. These estimates do not include the substantial potential benefits to the table grape and raisin grape industries, which would imply scaling up the measures of benefits by 20 percent or so, depending on the specific scenario being evaluated.

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TABLE 1:
Production Regions – Definitions and Basic Statistics

Production Region	Districts	Bearing Acreage, 2010	Tons Crushed, 2010	Yield per Acre, 2010	Average Price, 2010
		Acres	*Thousands of Tons*	*Tons per Acre*	*2008$/ton*
Napa-Sonoma		**100,424**	**331**	**3.30**	**2,479**
	3	55,647	192	3.45	1,974
	4	44,777	139	3.10	3,178
Coastal		**55,266**	**313**	**5.66**	**953**
	5	3,164	15	4.67	667
	6	6,563	28	4.23	974
	7	45,539	270	5.94	966
Northern SJV		**84,530**	**705**	**8.34**	**468**
	11	66,802	607	9.09	461
	17	17,728	98	5.52	515
Southern SJV		**132,215**	**1,831**	**13.85**	**284**
	12	28,220	270	9.56	353
	13	78,643	1,151	14.64	268
	14	25,352	410	16.19	285
S. California		**46,994**	**244**	**5.20**	**1,055**
	8	45,336	239	5.27	1,054
	15	646	1	1.66	783
	16	1,012	4	4.01	1,170
N. California		**37,489**	**165**	**4.38**	**887**
	1	16,276	66	4.05	1,101
	2	7,939	32	4.05	1,089
	9	7,064	49	6.89	406
	10	6,210	18	2.82	1,051
Total		**456,918**	**3,589**	**7.85**	**661**

Notes: "SJV" refers to San Joaquin Valley

TABLE 2

Average Annual Costs of PD and Ending the PD Control Program under Alternative Outbreak Scenarios, Relative to "Best Guess" Baseline

	Napa−Sonoma	Coastal	Northern San Joaquin	Northern California	Southern California	Southern San Joaquin Winegrapes	Southern San Joaquin Table and Raisin Grapes	State Total (Winegrapes Only)	State Total (All Grapes)
					$ (thousands per year)				
Silver Bullet									
Producer Surplus	23,118	472	−17	−522	5,042	3,335	8,730	31,428	40,158
Consumer Surplus	14,304	1,148	3,173	673	1,003	3,381	5,183	23,682	28,865
Net Benefit	37,422	1,620	3,156	151	6,045	6,716	13,913	55,110	69,023
Statewide Outbreak									
Producer Surplus	−86,970	1,262	7,609	3,413	−56,923	−29,698	−70,214	−161,308	−231,522
Consumer Surplus	−47,727	−6,970	−19,693	−4,223	−4,599	−22,253	−38,853	−105,464	−144,317
Net Benefit	−134,697	−5,708	−12,084	−810	−61,522	−51,952	−109,067	−266,772	−375,839
Napa−Sonoma Outbreak									
Producer Surplus	−87,165	1,348	4,052	824	1,197	2,701	0	−77,043	−77,043
Consumer Surplus	−47,476	−1,608	−4,536	−960	−1,399	−3,035	0	−59,014	−59,014
Net Benefit	−134,641	−260	−485	−136	−202	−335	0	−136,058	−136,058
Southern San Joaquin Valley Outbreak									
Producer Surplus	33	71	213	43	63	−32,965	−70,214	−32,541	−102,755
Consumer Surplus	−36	−85	−240	−51	−74	−18,306	−38,853	−18,792	−57,645
Net Benefit	−3	−14	−27	−7	−11	−51,271	−109,067	−51,333	−160,400
Southern California Outbreak									
Producer Surplus	164	3,537	10,623	2,162	−57,908	751	0	−40,671	−40,671
Consumer Surplus	−191	−4,400	−12,378	−2,626	−2,863	−887	0	−23,345	−23,345
Net Benefit	−26	−864	−1,755	−464	−60,771	−136	0	−64,016	−64,016

TABLE 3
Average Annual Costs of PD and Ending the PD Control Program, Relative to Alternative Baseline Parameterizations

	Napa−Sonoma	Coastal	Northern San Joaquin	Northern California	Southern California	Southern San Joaquin Winegrapes	Southern San Joaquin Table and Raisin Grapes	State Total (Winegrapes Only)	State Total (All Grapes)
					$ (thousands per year)				
Silver Bullet									
High Baseline	67,308	3,315	6,980	418	16,027	29,404	61,854	123,451	185,305
Best Guess Baseline	37,422	1,620	3,156	151	6,045	6,716	13,913	55,110	69,023
Low Baseline	6,494	74	659	141	3,214	489	0	11,070	11,070
Statewide Outbreak									
High Baseline	−103,947	−3,902	−7,954	−483	−51,488	−50,953	−61,126	−218,728	−279,854
Best Guess Baseline	−134,697	−5,708	−12,084	−810	−61,522	−51,952	−38,853	−266,772	−305,625
Low Baseline	−165,629	−7,280	−14,619	−820	−64,234	−58,163	−122,980	−310,745	−433,725

Notes: The Net Benefit is the sum of changes in consumer and producer surplus. The results for the “Best-Guess” scenario for the statewide outbreak are presented in Table 2 “High” and “Low” refer to the upper and lower bounds on range of estimated rates of PD losses.

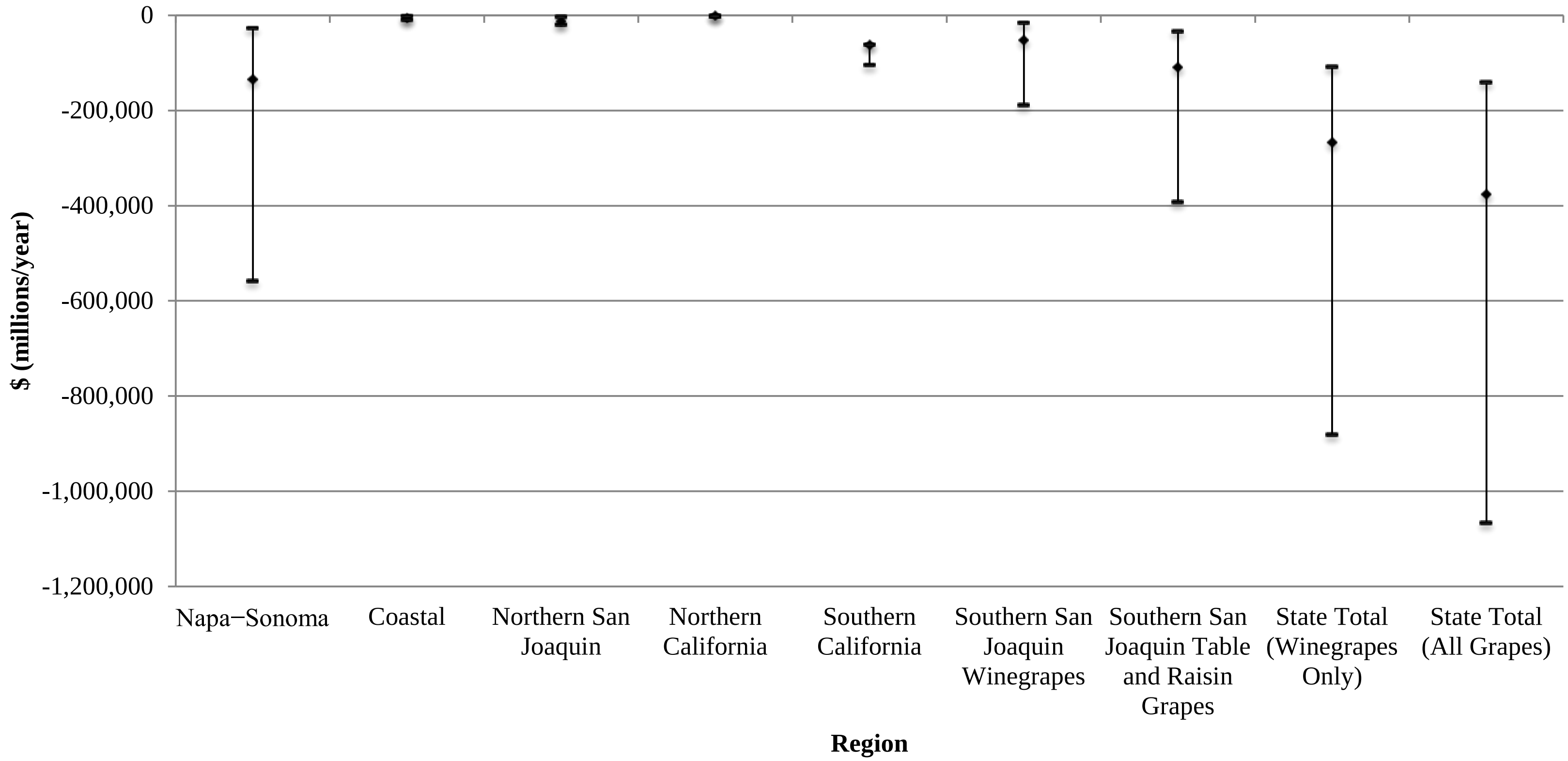
TABLE 4

Average Annual Costs of Ending the PD Control Program under Alternative Outbreak Scenarios, Relative to "Best Guess" Baseline

Region	"Best Guess" Outbreak			High Outbreak	Low Outbreak
	Producer Surplus	Consumer Surplus	Net Benefit (Loss)	Net Benefit (Loss)	Net Benefit (Loss)
	$ millions			*$ millions* (% Δ from "Best Guess")	*$ millions* (% Δ from "Best Guess")
Napa−Sonoma	−86,970	−47,727	−134,697	−557,561	−26,898
				314%	−80%
Coastal	1,262	−6,970	−5,708	−9,025	−1,076
				58%	−81%
Northern San Joaquin	7,609	−19,693	−12,084	−19,345	−2,346
				60%	−81%
Northern California	3,413	−4,223	−810	−1,881	−590
				132%	−27%
Southern California	−56,923	−4,599	−61,522	−104,271	−60,856
				69%	−1%
Southern San Joaquin Winegrapes	−29,698	−22,253	−51,952	−188,296	-15,676
				262%	−70%
Southern San Joaquin Table and Raisin Grapes	−70,214	−38,853	−109,067	−391,536	−32,856
				259%	−70%
State Total (Winegrapes Only)	−161,308	−105,464	−266,772	−880,379	−107,445
				230%	−60%
State Total (All Grapes)	−231,522	−144,317	−375,839	−1,065,941	−140,301
				184%	−63%

Notes: The Net Benefit is the sum of changes in consumer and producer surplus. Figures in parentheses below estimated Net Benefits are percentage differences between the estimate (i.e., "High" or "Low") and the corresponding "Best Guess" estimate. The results for the "Best-Guess" scenario for the statewide outbreak are presented in Table 2. "High" and "Low" refer to the upper and lower bounds on range of estimated rates of PD losses.

FIGURE 1:
Average Annual Costs of Ending the PD Control Program under Alternative Outbreak Scenarios



Notes: See notes to Table 4. Upper bound value equal to cost in the "Low Outbreak" scenario, middle value equal to "Best Guess" scenario, and lower bound value equal to "High Outbreak" scenario.

Appendices

Appendix A: Questionnaire

A questionnaire was sent to 28 individuals in late January, 2012. Two versions of the questionnaire were drafted. The first "short version" survey was constructed to gain feedback from individuals who would be knowledgeable mainly about the likely future of the disease in different areas of the state. This survey was centered on questions regarding current and future PD incidence rates in the six different regions of the state as defined in Table 1, both under current policy and if current programs were eliminated. The second survey, or the "long version," asked the same questions about disease incidence as well as questions regarding future winegrape production—specifically regional yields, quantity produced, and acreage—to be used, in part, to parameterize the "baseline" model. Two reminders were sent to individuals who did not reply.

Twelve individuals received the long version of the survey; of these recipients, seven responded; approximately 58 percent of survey recipients. Seventeen individuals received the short form of the survey, and eight responded; a 47 percent response rate. The surveys were sent to various groups of people considered to be Pierce's Disease experts; these included academic and government researchers as well as winemakers, farm advisors, vineyard managers, and pest control advisors. Responses were received from at least one individual from each group. Of the individuals who responded, many did not answer all of the questions, but only answered specific questions for region(s) with which they were most familiar. Many indicated they were hesitant to make what they saw as guesses about future events. Nonetheless, the responses that were received were helpful in formulating both relevant ranges and best guesses for baseline projections and scenarios.

Appendix Table A-1 includes a summary of survey results as well as the resulting baseline model parameters regarding future production. The “initial” values for yield, acreage, production, and price, were calculated as regional averages weighted by tons crushed, and averaged again over the three years 2008–2010 using Crush and Acreage Report data (California Department of Food and Agriculture/National Agricultural Statistics Service). For each category, the bottom row shows the value taken by the variable or parameter in the model, 50 years out, in 2061. Parameters defining the initial region-specific yield and its growth rate must be specified by the model user, so both the initial and 50-year values are the results of these specifications. Likewise, annual region specific loss-rates to PD are parameters that must be specified in the model. Future acreage and quantity produced are variables, the values of which are determined within the model; the values given in the last row for the respective categories are the equilibrium values from the model runs.

Table A-1 presents results from the long version of the survey only; this table shows the survey responses and the corresponding parameterizations or implied values for future production. The first section of this table is devoted to yields. In general, there was consensus among respondents that yields (tons of grapes produced per acre) would increase over time, although some individuals believed they would remain constant for some of the regions. The yields in 2061 that were chosen reflect an upward trend in yields that is stronger in some regions than in others. The Southern San Joaquin Valley, which currently has the highest yields (14.6 tons per acre), remains the highest yielding region after 50 years, with a model assumption of 18.2 tons per acre in 2061. Napa-Sonoma, which begins as the lowest-yielding (3.4 tons per acre) region in the State, remains the lowest-yielding region after 50 years with 5.0 tons per acre.

Most respondents said they expected that acreage in all regions would increase substantially during the 50-year time horizon, except in Napa-Sonoma, because almost all suitable vineyard land there is already in use. The model results produce acreages in 50 years that are largely in line with (or near) the range of survey responses. The model acreage in Napa-Sonoma expands slightly—approximately 8 percent, or 8,000 acres, which seems feasible over that time frame.

Production also increases in all regions, reflecting a combination of larger yields and acreages. Most respondents reported that they expected production in Napa-Sonoma to increase substantially, and this occurs in the model although not to the extent suggested by respondents. Because vineyard acreage is limited and yields in Napa are likely to remain quite low relative to other regions (this was generally agreed upon by respondents), the very high production suggested is not feasible.[9]

[Table A-1: *Summary of Questionnaire Results: Future Production*]

Table A-2 reports survey results (from short and long survey versions) about current and future PD-related losses of vines. Respondents had wide-ranging and often conflicting opinions regarding PD incidence, both under the current program and if programs would cease to exist. This questionnaire asked about average vine deaths per 1,000 resulting from PD over the next 10–20 years. In general, respondents concurred that very little PD losses occur in four regions: Coastal, Northern California, or the Northern or Southern San Joaquin Valley.[10] Napa-Sonoma

[9] There may have been some confusion regarding the time horizon in this question. Only one person responded regarding production over the 25-year time frame that the survey asked about, although several others indicated that production numbers could be calculated from yield and acreage responses, which were over a 50-year time horizon.

[10] Some isolated areas of Santa Cruz County were reported to have Pierce's Disease problems, but that county produces only very small amounts of grapes.

and Southern California are hotspots, with estimates of between one and 10 vines per 1,000 dying per year in these regions.

Ranges were even wider regarding potential losses if the current PD program were to end, from a view that losses would remain the same as at present to a view that losses would rise to roughly 100 vines per 1,000 in Napa-Sonoma and Southern California. Respondents thought that the baseline rates of losses to PD in a no-policy scenario should remain at zero in Northern California; should remain relatively low in the Coastal region and the Northern San Joaquin Valley; and should be higher in the Southern San Joaquin Valley, Southern California, and Napa-Sonoma. Specific estimates of likely loss rates varied among respondents though they ranked the regions similarly.

[Table A-2: *Summary of Questionnaire Results: Pierce's Disease*]

Appendix B: Tables

TABLE A-1
Summary of Questionnaire Results: Future Production

	Napa-Sonoma	Coastal	Northern San Joaquin Valley	Southern San Joaquin Valley	Southern California	Northern California
Yield (*tons/acre*)						
Initial Yield	3.4	6.4	8.9	14.6	5.7	4.7
Survey Response Ranges, Yr. 50	3.4 – 7.2	7.1 – 10.0	9.8 – 15.0	13.0 – 25.0	5.7 – 10.0	5.2 – 10.0
Number of Responses	5	4	4	4	3	2
Model Yield, Yr. 50	5.0	7.1	11.1	18.2	6.3	5.2
Acreage (*1,000s, bearing acres*)						
Initial Acreage	99.7	51.4	82.4	133.3	45.9	37.2
Survey Response Ranges, Yr. 50	99.7*	51.4 – 73.9	82.4 – 132.7	133.3 – 208.1	45.9 – 60.0	37.2 – 50.0
Number of Responses	5	4	4	4	3	2
Model Acreage, Yr. 50	107.6	70.2	123.9	181.5	71.2	56.8
Production (*1,000s, tons*)						
Initial Production	323.5	281.2	746.3	1,715.6	208.8	152.7
Survey Response Ranges, Yr. 25	340.0	281.2	746.3	1,715.6	208.8	-
Survey Response Ranges, Yr. 50	511.2 – 734.1	399.3 – 738.7	1,676.5 – 2,032.9	4,000.0*	600.0*	500.0*
Number of Responses	4	4	4	3	3	1
Model Production, Yr. 50	414.3	375.4	1,133.8	2,675.4	331.1	228.6

* Survey respondents did not provide any other suggestions.

TABLE A-2:
Summary of Questionnaire Results: Pierce's Disease

Region	With Current Policies and Technology			Without Current Policies		
	Suggested PD Losses, after 10–20 Yrs	Number of Responses	Best-Guess PD Losses	Suggested Losses after 10–20 Yrs	Number of Responses	Best-Guess PD Losses
	(Vines/1,000)		*(Vines/1,000)*	*(Vines/1,000)*		*(Vines/1,000)*
Napa-Sonoma	1 – 10	10	6	10 – 100	6	24
Coastal	0 – 2	6	1	0–5	4	4
San Joaquin Valley North	0 – 2	6	1	0–5	5	4
San Joaquin Valley South	0 – 8	7	2	8 – 40	5	15
Southern California	2 – 10	5	4	40 – 90	4	40
Northern California	0*	4	0	0	4	0*

* Survey respondents did not provide any other suggestions.

TABLE A-3
Baseline Model Parameters

Parameter	Interpretation	Region	Value	Source/Notes
g	Yield growth rate as % of initial yield per year	Napa-Sonoma Coastal Northern SJV Southern SJV S. California N. California	0.9% 0.2% 0.5% 0.5% 0.2% 0.2%	Regression results, consultation with industry experts.
c_1	Unit cost coefficient in plantings cost Equation (5.7a)	Napa-Sonoma Coastal Northern SJV Southern SJV S. California N. California	16,249 5,764 4,546 2,482 5,882 5,494	Assumptions about the supply elasticity of new investment, various UCCE Cost and Return Studies.
c_2	Cubic cost coefficient in plantings cost Equation (5.7a)	Napa-Sonoma Coastal Northern SJV Southern SJV S. California N. California	0.00119 0.00172 0.00101 0.00035 0.00270 0.00377	Assumptions about the supply elasticity of new investment, various UCCE Cost and Return Studies.
δ_0	Assumed acres lost by natural death	1 % per year for all regions.		Discussion with industry experts
δ_1	Assumed acres lost to Pierce's Disease (baseline)	Napa-Sonoma Coastal Northern SJV Southern SJV S. California N. California	0.6% 0.1% 0.1% 0.2% 0.4% 0.0%	Survey responses, discussion with industry experts
c_3	Unit cost coefficient in vine replacement cost Equation (5.13)	Napa-Sonoma Coastal Northern SJV Southern SJV S. California N. California	17,910 6,512 4,594 3,395 6,592 6,328	Various UCCE Cost and Return Studies.
c_4	Quadratic cost coefficient in vine replacement cost Equation (5.13)	Napa-Sonoma Coastal Northern SJV Southern SJV S. California N. California	0.00132 0.00194 0.00102 0.00048 0.00302 0.00435	Various UCCE Cost and Return Studies.
v_0	Independent variable cost from Equation (5.17)	$0 per acre for first three years, increasing to year 5.		Various UCCE Cost and Return Studies
v_1	Variable cost based on the supply of land; Equation (5.17)	$20 and 14.3 per acre for Napa-Sonoma and Southern SJV, respectively, 0 elsewhere.		Various UCCE Cost and Return Studies
v_2	Variable PD mitigation cost; Equation (5.17)	$150/acre in Napa-Sonoma, Coastal, and S. California, 0 elsewhere.		Industry experts, pest control advisors
r	Real discount rate.	4% for benefit/cost analysis; 5% for producer profit maximization problem.		
T	Lifespan of the investment.	50 years, acreage calculated over 75 years.		Based on two-25-year vineyard lifespans

APPENDIX TABLE A-4
Demand-Side Baseline Model Parameters

	$\bar{p}_j$	$\bar{q}_j$	f_j		
			Low	Medium	High
Low	336	1,715,645	−0.0000271	−0.0000030	−0.0000191
Medium	898	1,388,979	−0.0000009	−0.0000902	−0.0000681
High	3,277	323,531	−0.0000004	−0.0000045	−0.0020243