THESIS

THE ECONOMIC BENEFITS OF BIRD CONTROL IN U.S. CHERRY PRODUCTION

Submitted by

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ABSTRACT

THE ECONOMIC BENEFITS OF BIRD CONTROL IN U.S. CHERRY PRODUCTION

Bird damage is a common and costly problem for fruit producers, who try to limit damage by using control techniques. This analysis used a survey presented to producers in five states to estimate the damage sustained to sweet and tart cherry crops with and without the use of bird control. A modified partial equilibrium model was applied to the data to estimate the change in marginal cost of production resulting from a ban on bird control, incorporating both decreased output and elimination of control costs. Welfare analysis was conducted for both crops with short and long run supply elasticities derived from time-series data using geometric distributed lags. Total surplus for both crops combined decreases by about $166 to $216 million in the short run and $23 to $31 million in the long run with no bird management, indicating that bird control has a large impact on cherry production and associated market outcomes.

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Chapter One: Introduction

1.1 U.S. Cherry Production

The United States is the world's second-largest cherry producer, after Turkey, accounting for 15% of the world's output. Cherries are becoming an increasingly important fruit crop. They were ranked the eighth most valuable fruit and nut crop in 2010 and generated $762 million in U.S. farm cash receipts (ERS 2012a). Production of the two major types of cherries, sweet and tart (sour), has expanded in recent years. Bearing acreage for sweet cherries has increased steadily over the last decade. Bearing acreage for tart cherries was decreasing but appears to be on the rise again with a gain of 2,000 acres in the last five years (NASS 2012). Part of the production expansion is a response to the steady increase in demand over the past several decades resulting from findings that suggest cherries have extensive health benefits. They are a rich source of antioxidants useful for preventing cancer and heart disease, and cherries may also relieve pain associated with arthritis, gout, and headaches (ERS 2012a).

Michigan, Oregon, California and Washington account for about 98% of total U.S. sweet cherry production. Almost 70% of tart cherry production occurs in Michigan (NASS 2012). Sweet cherries are increasingly utilized fresh (about 75%), and the rest are processed, often as maraschino cherries. Tart cherries are mostly processed and used in baked goods, juices and snacks (MSU 2012). Less than one percent of tart cherries are for fresh use (ERS 2012a).

Imports account for a small portion of cherry utilization in the U.S., about eight percent, almost exclusively from Chile. The U.S. competes with Turkey to be the leading exporter of cherries worldwide, averaging 117 million pounds in 2005-2009, valued at $261.4 million. Exports account for about 16% of total U.S. cherry production.

While demand for cherries is relatively stable from year to year, cherry production can fluctuate widely due mostly to weather factors and the alternate-bearing tendency of the trees (the biological pattern of low and high levels of production in alternate years for an individual tree). At the same time, supply is inelastic in the short run because cherry orchards take years to establish. Consequently, prices may vary drastically from year to year.

1.2 Economics of Pesticide Restrictions

Many studies have examined the economic impacts of various pest control restrictions and regulations for a wide range of crops. Most use some estimate of additional yield lost without the use of a particular pesticide to calculate the value of damage avoided by current use of the pesticide. Some measure value by using welfare analysis, while others only calculate the revenue lost to producers. The following is a summary of several relevant studies and their results.

Lichtenberg et al. (1988) developed a partial equilibrium model to estimate net social (total) welfare costs and their distribution given a change in pesticide regulations, specifically, the cancellation of the insecticide ethyl parathion. The model was applied to three tree crops: almonds, plums, and prunes. Costs of pesticide and changes in yield were modeled as constant across all output, implying a parallel shift in the supply curve. Elimination of the pesticide causes redistribution of income among producers who use the pesticide and those who don't, with nonusers gaining one-fourth to one-third of users' losses. The magnitude of redistribution increases as demand elasticity decreases and supply elasticity increases. In other words, as demand becomes more inelastic producers' collective loss decreases (by moving surplus from one producer to another rather than to consumers) and consumers' loss increases. When demand is very inelastic consumers may bear up to 90% of the social cost resulting from a change in pesticide regulations. Almonds and prunes have significant export markets and the authors differentiate between domestic and foreign consumers. A single price is used for each crop, but domestic and foreign demand elasticities are allowed to vary. This results in different welfare impacts for domestic and foreign consumers. Foreign demand is estimated to be more inelastic than domestic demand, so foreign consumers bear the majority of the cost in the short run.

An analysis of the impact of cancellation of an important fungicide, sodium ortho-phenylphenate (SOPP), on the grapefruit industry was conducted by Buzby and Spreen (1995). The analysis used grapefruit production in Florida as a proxy for all grapefruit production in the U.S. because the majority (85%) of production occurs in that state, and almost all exports (99%) come out of Florida. The U.S. is a net exporter of grapefruit, with about 40% of fresh product exported and no significant imports. The pesticide in question, SOPP, does not affect yield but instead prevents infection during transportation, thereby extending the shelf-life of the fruit. A spatial equilibrium model was used in the study which incorporated the reduced shelf-life and increased spoilage by increasing the quantity of fresh fruit required to be produced to maintain the quantity sold at market. This study also allowed domestic and foreign demand to vary: domestic demand was assumed to be elastic while foreign demand was inelastic. Therefore, for processed fruit, total revenue decreased in the domestic market but increased in the export market. For fresh fruit, total revenue decreased for both domestic and foreign markets. Overall, the analysis found that producers faced a significant loss in total revenue under three different yield loss scenarios (2%, 5%, and 10% losses), and some of the effects were passed on to consumers in the form of higher wholesale prices. The cost of postharvest losses to the grapefruit industry ranged from two to twelve million dollars. Similar to the Lichtenberg study, foreign demand is more inelastic than domestic demand, so foreign consumers face greater losses from the cancellation of a pesticide than domestic consumers.

Similar to pesticide use, a virus prevention program (VPP) for crops reduces yield loss and the associated increased costs. Cembali et al. (2003) estimated the value of a VPP for fruit trees, specifically apples, sweet cherries, and Clingstone peaches. A welfare analysis was conducted for growers, nurseries, and consumers. Viral damage is manifested as unmarketable fruit, reduced yield, and tree death. Estimates of yield loss due to viruses taken from the literature range from 12% to 67% for apples, 18% to 30% for Clingstone peaches, and 19% for sweet cherries. Changes in consumer and producer surplus were estimated by assuming a parallel shift in the supply curve resulting from the decreased yield, or equivalently, the increase in cost per unit produced. A single pair of supply and demand elasticities, all inelastic, was used for each fruit. The benefits of a VPP were $80,000,000 for growers, $488,000 for nurseries, and $147,000,000 for consumers. Again, consumers see the largest impact from a change in virus control because demand elasticities are more inelastic than supply elasticities. Exports were not considered in this analysis.

1.3 Bird Damage to Fruit Crops

Birds are one of the most significant pests for fruit crops (Virgo 1971). A USDA study (USDA 1998) reported that U.S. apple and grape producers lose tens of millions of dollars each year due to direct bird damage and expenditures on insufficient control measures. Birds reduce crop yields by consuming fruit, damaging fruit and leaving it susceptible to infection, and causing fruit to be harvested before it is fully ripe which results in inferior products (Dellamano

2006). Since the majority of cherries are sold fresh, even minimal damage can reduce a crop's marketability.

Many control measures for birds exist, and some are more controversial than others. Chemical repellents, specifically the insecticide methiocarb, were used for decades. They were banned in the early 1990's due to toxicity effects, and an effective chemical repellent has not been available for use since. Recently methyl anthranilate, a natural compound found in grapes, was discovered to have a minor repellent effect. It is produced in large quantities as a food additive for products like grape soda and is not harmful to humans. Unfortunately, methyl anthranilate must be applied to crops frequently and in very high doses to have an effect on birds. Trapping and shooting birds are alternatives but are controversial and illegal in some regions. Scare methods, such as scarecrows and distress calls, are often ineffective, while propane guns and displaying dead birds are not amenable to operations in which customers pick their own fruit. Netting (covering orchards with nets) has been found to be highly effective but is also very expensive and labor intensive (Simon 2008). A method for bird management that is effective, inexpensive, and noncontroversial has yet to be discovered, but would be very useful to producers.

Although current bird control methods are not ideal, they are still widely used by fruit producers to reduce yield loss and increase productivity and profitability. Increases in output due to reduced costs imply decreases in price in agriculture markets, due to their competitive nature. The economic benefits of reduced yield loss extend to consumers in the form of lower prices, to producers as increased income, and to society in general through secondary effects such as job creation.

Cummings et al. (2005) studied the economic impacts of blackbird damage to rice crops. $3.2 million was spent in 2001 on mitigation attempts in five states: Louisiana, Texas, Arkansas, California, and Missouri. Producers estimated losing between 6% and 15% of their crop to birds and spent an average of $914 on bird management. The value lost by producers due to damage was estimated at $21.5 million that year. The authors emphasize the impact of reduced yields on the nation's export capability and dependence on imports, and suggest that new and improved methods of bird control would be beneficial to rice producers and consumers, and to the U.S. economy on the whole.

A relatively small amount of research has been done on the economic impacts of bird damage to fruit crops. Much of this research has focused on wine grapes (Crase et al. 1976, Berge et al. 2007, Gadd 1996). Boyce et al. (1999) studied the economic impacts of bird damage in vineyards of the Marlborough Region of New Zealand. The study provides a comprehensive analysis of the various control methods used in the region, their efficacy, costs, and estimates of damage with and without bird control as reported by area producers. The average cost of bird control per hectare was $440. A welfare analysis was not performed; instead the value of the crop lost to bird damage was calculated by multiplying the amount of yield lost by the price of the crop. The use of bird control is estimated to save $7.5 million for the region, and value lost with no bird control is estimated to be $8.6 million, meaning that current bird damage causes a loss of $1.1 million. A benefit cost analysis is performed in which the cost of bird control ($1 million) is compared with the benefits of bird control ($7.5 million). The result is a benefit-cost ratio of 7.5:1, meaning every dollar spent on bird control saves $7.50 in damage.

A comprehensive study of bird and rodent damage to 19 crops in California was performed by Gebhardt et al. (2011). The study consisted of a meta-analysis of the current literature on pest damage, as well as interviews with various agricultural experts, to establish a single estimate of pest damage to each crop. Expert estimates were found to be 7.7% higher than estimates obtained from surveys and field studies. Two estimates of bird damage were reported for cherries: a field study reported between 7.62% and 10% damage per acre, and an expert interview provided an estimate of 50% damage per acre. Reported estimates were weighted by the percent of acreage affected by pests and then averaged to obtain a single estimate for percent of yield lost. The result for cherries was 3.8%. The study concludes that damage from birds and rodents is substantial despite the use of control methods, indicating a need for more effective methods, or efforts to reduce the cost of currently available effective methods.

The studies summarized above examined the impacts of bird damage to crops, focusing on bird damage to wine grapes and pest damage to multiple crops, but did not provide information about the economic impact of bird damage to cherries. A study focusing specifically on bird damage in cherry production nation-wide may be useful to producers and policymakers when making decisions about control measures, as well as to researchers developing new technologies for bird control.

1.4 Microeconomic Effects of Reduced Crop Yield in a Competitive Market

A perfectly competitive market has several important characteristics (Snyder & Nicholson, 2008):

1. There are a large number of firms, producers, or sellers,
2. Each firm produces an identical product (homogeneous products),

3. Individual firms are price takers; they cannot affect price by changing production,
4. There are no barriers to entry or exit in the market.

Perfect competition is rare in reality, but it is often assumed for agricultural markets (Rude & Meilke, 2004) because they closely adhere to the requirements outlined above. Agricultural firms tend to be small and numerous, and their products are generally indistinguishable. Consequently, they do not have the ability to set their own prices, but must accept the market price. Additionally, entry into the market is relatively easy, accomplished by planting on a piece of land, and exit is even easier. The assumption of perfect competition allows a more straightforward determination of new equilibrium given changes to the market, and subsequent welfare analysis.

Economic theory indicates a competitive market with many buyers and sellers will move toward an equilibrium price and quantity through market interactions. Equilibrium represents the most efficient allocation of resources because social surplus is maximized at this point. Total surplus is divided into two categories: consumer and producer surplus. Consumer surplus is willingness-to-pay that is in excess of the equilibrium price. It represents the net gain achieved by paying less for a good than the consumer's valuation of that good. Graphically, it is the area below the demand curve and the above the price. Similarly, producer surplus is willingness-to-accept that is below the equilibrium price, or the gain to producers for selling a good for more than the minimum price they require. Graphically, producer surplus is the area above the supply curve and below the price.

In a competitive market, the supply curve is defined as the portion of the marginal cost curve above the minimum of the average variable cost curve (the shutdown point). Marginal cost of production is the cost required to produce one additional unit of a good. Firms increase production until the market price equals the marginal cost. They will stop producing when their marginal cost is higher than the market price. Aggregate supply in a competitive market is the sum of the quantity supplied by individual producers.

Figure 1 represents a competitive market in equilibrium. P* and Q* are the equilibrium price and quantity, respectively. *A* and *B* are consumer and producer surplus. Total surplus is *A* + *B* and is at its maximum given P*.

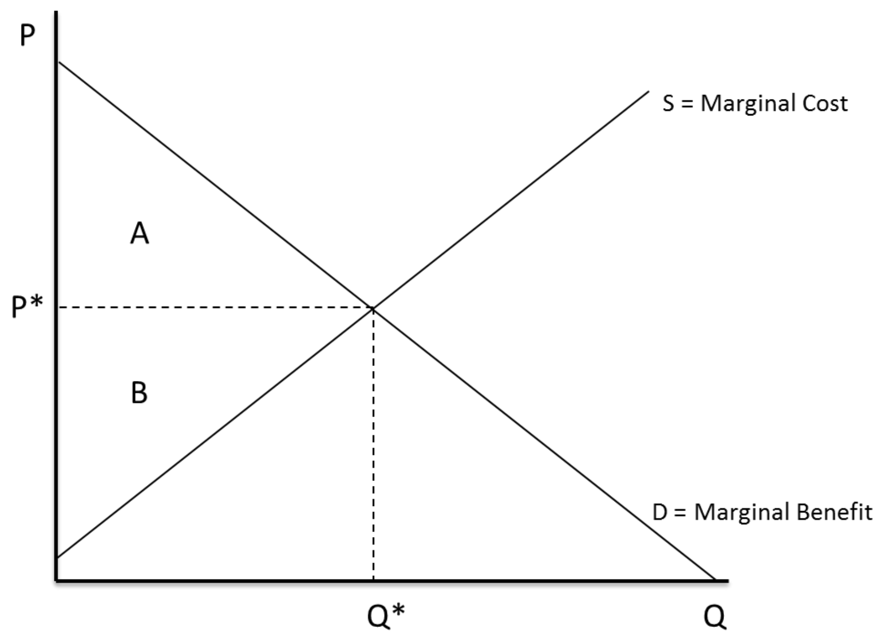

Figure 1. Market equilibrium with consumer (A) and producer (B) surplus

The cost of pest control is reflected in the marginal cost curve. If new regulations were introduced that banned bird control methods, there would be two shifts in the marginal cost curve. First, it would shift to the right (*MC'*) reflecting the elimination of bird control costs, as illustrated in Figure 2. However, without the control methods, birds would destroy a greater portion of the crop, resulting in lower yield. Therefore, the cost of each unit of the good increases, causing the supply curve to shift to the left (*MC''*). The extent of bird damage with no control determines how far the curve shifts, but it must shift to a position farther left than the original supply curve. Otherwise, the cost of bird control would be greater than the revenue from avoided bird damage and producers would not have chosen to use bird control.

Decreased yield causes an increase in cost per unit of output resulting in higher prices, and the welfare of both consumers and producers is affected. Consumer surplus (Figure 2) decreases by an amount equal to the area *GCD* while producer surplus decreases by *EF* but gains *G*. Total surplus decreases by the area *CDFE*.   Consumer surplus must decrease, but producer surplus may increase or decrease depending on the elasticities of supply and demand. If the area of *EF* is greater than *G* then producer surplus decreases. If *EF* is smaller than *G* then producer surplus will increase.

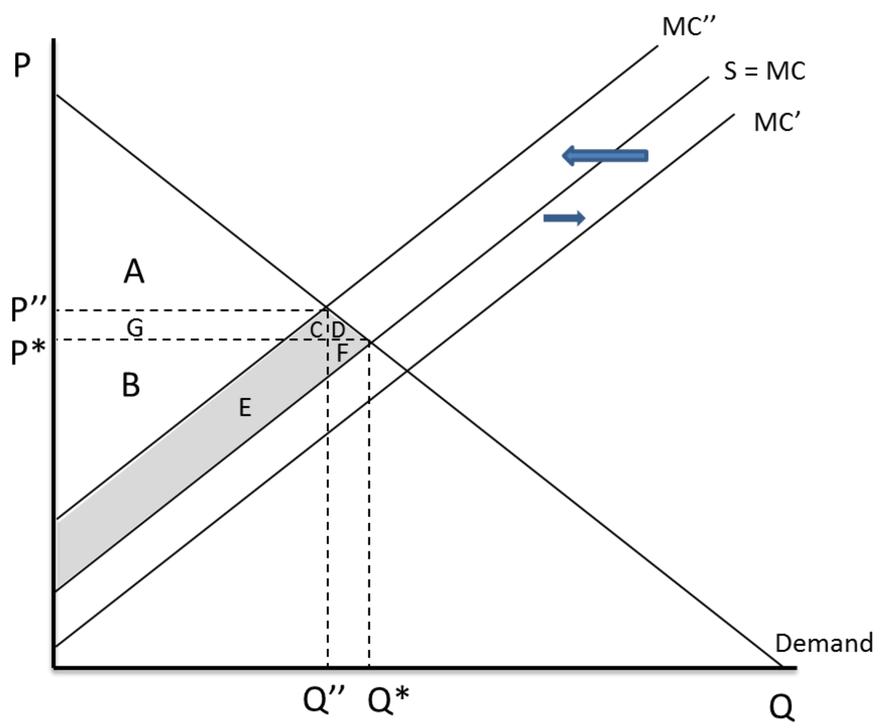

Figure 2. Change in social surplus when bird control is banned

The magnitude of surplus changes is affected by price elasticities, which measure the responsiveness of producers and consumers to a change in price. An inelastic supply or demand curve indicates that a one percent increase in price causes less than a one percent change in quantity supplied or demanded. If a one percent price change causes a change in quantity supplied (demanded) of greater than one percent, then supply (demand) is said to be elastic. As the supply curve becomes more elastic (horizontal), producer surplus decreases. Similarly, consumer surplus increases as the demand curve becomes less elastic.

Most crops have a very inelastic supply in the short run because inputs, (e.g. acreage, labor), are not easily adjusted. In a given year supply is often said to be perfectly inelastic because whatever producers planted at the beginning of the year determines how much will be harvested. So, ignoring the possibility of stocks, supply is fixed for some period of time. Over time the supply curve can become less inelastic and may be very elastic in the long run.

This study analyzes the economic effects of a bird control ban on cherry production and consumption, and estimates the market outcomes of decreased yield and eliminated control costs. Although a total ban on all control is unlikely, various specific methods of bird control may be restricted or made illegal. For this analysis, bird control is considered one type of pest control among many used by producers, and its use or disuse is modeled as a change in the marginal cost of production. The analysis will elucidate the economic benefits of bird management for both producers and consumers, and may be useful for policymakers when considering future regulations and for producers when making implementation decisions.

Chapter Two: Methodology

2.1 Data Collection

A mail survey was distributed to fruit growers in Michigan, New York, Oregon, Washington, and California in the spring of 2012, targeting producers of Honeycrisp apples, blueberries, wine grapes, and sweet and tart cherries (Anderson et al. 2013). The survey consisted of 21 questions soliciting information about acreage, yield, estimates of bird damage, and bird control techniques with their associated costs. A total of 7,666 surveys were distributed and 2,351 completed surveys were returned; a 30.7% response rate. Of those returned 1,590 grew one of the crops listed above, and of those, 698 grew cherries.

Producers were asked to estimate their yield lost due to bird damage in 2011, their expected yield loss if they had not used any bird management methods, and their expected yield loss if they and their neighbors had not used any bird management methods. The two differences between yield loss with no management and yield loss with management provide a low and high estimate of the economic benefits of bird control. Benefits are a function of the value of the crop and the effectiveness of control measures.

The price of cherries varies by state and year of production due in part to differences in quality and because different varieties of cherries are better suited for production in different regions. The average price of sweet cherries ranged from $590 per ton in Michigan to $2,597 per ton in New York from 2008-2010 for a nationwide average of $1967 per ton (ERS 2011). Tart cherries averaged $0.30 per pound, with a high of $0.35 per pound in Oregon and a low of $0.25 per pound in Michigan. These prices are based on U.S. farm cash receipts, which represent the prices received by farmers when selling in domestic and foreign markets (ERS 2012b). A single price is used for the analysis under the assumption of product homogeneity.

Varietal differences are considered small enough that all sweet and tart cherries are regarded as two single products. The U.S. is a net exporter of cherries, claiming the second largest share of the export market worldwide, exceeding all other exporting countries except Turkey (FAO 2012). The third largest exporter is Chile, but due to its location in the southern hemisphere, cherry production occurs at a different time of year and so Chile is not considered a competitor in the export market. Spain is the fourth largest exporter, but the U.S. exports about three times the amount of cherries that Spain exports. Therefore, the U.S. export market share for cherries is substantially larger than all other exporting countries with the exception of Turkey. For this analysis, it is assumed that changes in production will affect the domestic price of cherries, as well as the world price, since the U.S. is a large producer in the world market.

2.2 Partial Equilibrium Model

A partial equilibrium model is an economic model in which only one factor is allowed to change while everything else that could potentially affect the market is held constant. Prices and quantities produced are allowed to adjust until they are in equilibrium through market interactions between suppliers and consumers. Consumer income and prices of substitutes and complements are assumed not to change. Additionally, changes in a given market are assumed to have no impact on other markets. This type of model makes analysis of the effects of single changes much simpler.

An adaptation of a partial equilibrium model developed by Anderson and Shwiff (2013) was applied to the survey data. In this model producers explicitly choose to employ bird management. Supply and demand elasticities, market price, production data, and cost-effectiveness of bird control are necessary to apply the model. Demand elasticities and price and production data are available for cherries. Sweet and tart cherries had demand elasticities of -0.558 and -0.381, respectively (Cembali et al. 2003). Estimates of control costs and crop damage are obtained from the survey results. Supply elasticities are derived in the following section. Perfect competition, identical producers, and product homogeneity are assumed for this model.

Profit maximization for each producer is given by

$$\max \pi = Pq(X, Z) - xX - zZ,$$

where *X* is the number of acres harvested in a given year, *Z* is the number of acres to which bird control is applied, *x* is the per-acre production cost excluding the cost of bird control, *z* is the per-acre cost of bird control, and *P* and *q* are market price and quantity produced. First order conditions are

$$\frac{\partial \pi}{\partial X} = P\frac{\partial q}{\partial X} - x = 0 \text{ and } \frac{\partial \pi}{\partial Z} = P\frac{\partial q}{\partial Z} - z = 0,$$

implying that producers will use bird control on an acre if the additional revenue gained from doing so is greater than the cost. Input demand functions are

$$X^* = X(P, x, z) \text{ and } Z^* = Z(P, x, z),$$

where X^* and Z^* are the optimal quantities of acres harvested and bird control given current regulations. Assuming linearity, the individual supply function is

$$q^* = q(X^*, Z^*) = q(P, x, z) = a + bP.$$

Market supply and demand are given by

$$Q_S = \alpha + \beta P \text{ and } Q_D = \delta + \gamma P,$$

where $\beta = \frac{E_S Q_1}{P_1}$, $\alpha = Q_1 - \beta P_1$, $\gamma = \frac{E_D Q_1}{P_1}$, and $\delta = Q_1 - \gamma P_1$.

At market equilibrium:

$$Q = \frac{\left(-\frac{\alpha}{\beta}\right)+\left(\frac{\delta}{\gamma}\right)}{\left(\frac{1}{\gamma}\right)-\left(\frac{1}{\beta}\right)} \text{ and } P = \left(-\frac{\delta}{\gamma}\right) + \left(\frac{Q}{\gamma}\right).$$

A ban of bird control would restrict *Z* to zero and change the producers' marginal cost functions from

$$MC = -\frac{a}{b} + \frac{q}{b} \text{ to } MC_2 = \frac{-a}{b} + k + \frac{q}{b(1+L)},$$

where

$$k = \frac{\Delta z}{yield\ per\ acre} \text{ and } L = \frac{\Delta\ yield\ per\ acre}{yield\ per\ acre}.$$

Then the change in marginal cost is given by

$$\Delta MC = k - \frac{qL}{b(1+L)}.$$

Control cost per unit produced is represented by *k* and is constant across all output. Elimination of all bird control would make the numerator of *k* the negative of what is currently being spent per acre on bird control. *L* is the percent reduction in yield due to elimination of bird control, and causes the change in marginal cost to increase as production increases, and decrease as production decreases. The new marginal cost (MC_2) is obtained by adding *k* to the original marginal cost equation and solving for q, then multiplying by (1+L) and solving for MC. Subtracting MC from MC_2 gives the change in marginal cost. The two terms in this equation reflect the two opposing shifts of the supply curve (Figure 3), the first being the removal of control costs reflected as a parallel shift to the right to *S'*, and the second the decrease in production resulting from bird damage reflected as a leftward pivot to *S''*.

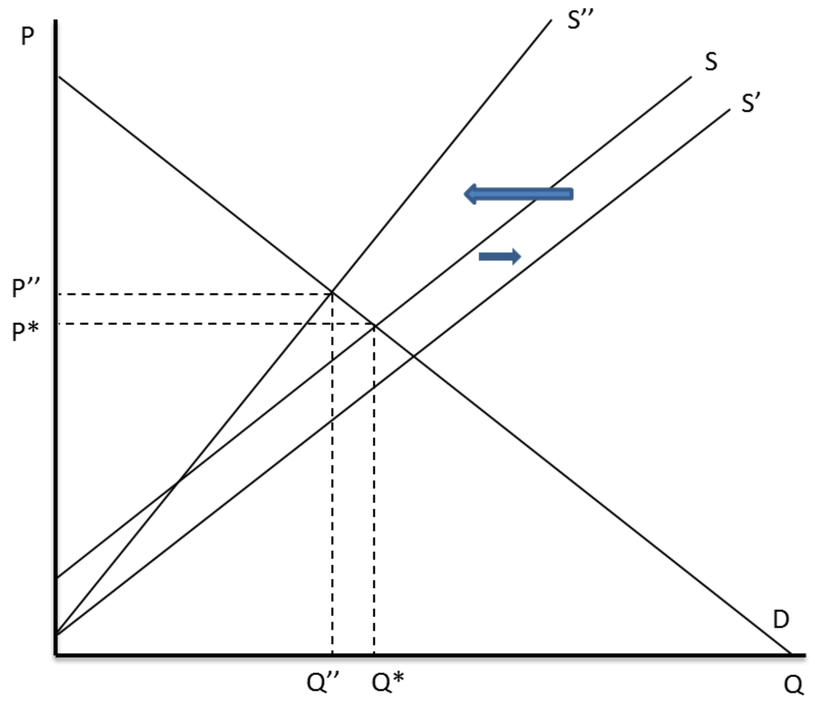

Figure 3. Shifts of the supply curve in response to changes in bird control.

The change in bird management results in a new equilibrium given by

$$P_2 = \frac{\alpha + \alpha L - k\beta - k\beta L - \delta}{\gamma - \beta - \beta L}.$$

The market-wide changes in consumer and producer surplus are given by

$\Delta CS = \int_{P_2}^{P_1} (\delta + \gamma P) dP$ and $\Delta PS = \int_{P_2}^{P_1} (\alpha + \beta P) dP$.

2.3 Derivation of Supply Elasticities

A range of supply elasticities was estimated for this study for two reasons. First, an estimate of the price elasticity of supply for cherries could not be found in the published literature. Studies that include cherry production generally use the elasticity of another fruit crop, usually apples (Cembali et al. 2003). Since this study is focused solely on cherries, a cherry-specific supply elasticity seemed useful. Secondly, supply elasticities for crops are known to change over time, increasing from short run to long run production. Therefore, a single value would not capture the change in welfare given various time frames. A set of elasticities ranging from short-run to long-run provides a more dynamic analysis of changes in production.

Producers choose the quantity of a good they will supply based on the market price of that good. Growers cannot respond to the current year's price when considering whether to expand or reduce orchards because they don't know what it will be. Instead, they look back at prices from previous years to predict what future prices might be, and use this information to determine what their long-term investment in orchards should be. These expectations are likely formulated using information from several past years, and can be measured using distributed lags.

A model using geometric distributed lags was applied to thirty years of price and production data (ERS 2010). This model, as described by Ferris (2005), uses OLS regression to predict the quantity produced in a given year *t* based on the price and quantity produced in the previous year. It begins with a supply equation in which production is a function of past prices:

$Q_t = \alpha + \sum_{i=1}^{\infty} \beta_t P_{t-i}$

where $\beta_i = \beta\lambda^i$; $0 < \lambda < 1$; $i = 1,2 \ldots \infty$. So price becomes less important as it moves farther back in time. This assumes that producers weigh prices in recent years more heavily when deciding how much to produce.

The OLS equation is obtained with the following steps:

1. Begin with two lagged supply equations, one starting in year *t* and the other lagged by one year:

   (a) $Q_t = \alpha + \beta\lambda P_{t-1} + \beta\lambda^2 P_{t-2} + \ldots + \beta\lambda^{\infty} P_{t-\infty}$

   (b) $Q_{t-1} = \alpha + \beta\lambda P_{t-2} + \beta\lambda^2 P_{t-3} + \ldots + \beta\lambda^{\infty} P_{t-\infty}$

2. Multiply (b) by λ

   (c) $\lambda Q_{t-1} = \lambda\alpha + \beta\lambda^2 P_{t-2} + \beta\lambda^3 P_{t-3} + \ldots + \beta\lambda^{\infty} P_{t-\infty}$

3. Subtract (c) from (a)

   (d) $Q_t - \lambda Q_{t-1} = \alpha - \lambda\alpha + \beta\lambda P_{t-1}$

   (e) $Q_t = (1-\lambda)\alpha + \lambda Q_{t-1} + \beta\lambda P_{t-1}$

The terms 1- λ, λ, and $\beta\lambda$ can be identified as OLS coefficients. $\beta\lambda$ (the price coefficient) is the impact multiplier for a one-year lag, $\beta\lambda + \beta\lambda^2$ for a two-year lag, and so on resulting in $\beta\lambda/(1-\lambda)$ in the long run.

Elasticities are expressed as

$\beta\lambda * (\frac{P_{t-1}}{Q_{t-1}})$, 1-year lag

$(\beta\lambda + \beta\lambda^2) * (\frac{P_t}{Q_t})$, 2-year lag

$(\frac{\beta\lambda}{1-\lambda}) * (\frac{P_{t+\infty}}{Q_{t+\infty}})$, long run.

Once the regression estimates are obtained, iterations of the equation are performed holding price constant throughout while updating the lagged quantity each period with the value obtained in the previous period. The process is repeated raising price by one unit. Iterations are carried out until the elasticity begins to converge on one point. The result is a range of supply elasticities over time.

Chapter Three: Results and Discussion

3.1 Survey Results

Of the 7,666 mail surveys sent out to producers 2,351 completed questionnaires were returned for a 30.7% response rate. Of these 698 grew cherries; 644 grew sweet cherries and 214 grew tart cherries. 160 producers grew both varieties. Responses were distributed relatively evenly between the five states surveyed.

519 cherry producers (74%) reported taking some action to deal with bird damage. Operations ranged in size from less than one acre up to 2,000 acres. Average acreage was 41 and 75 acres for sweet and tart cherries, respectively. On average, sweet cherry producers spent $1,430 ($28 per acre) on bird control in 2011; tart cherry producers spent $329 ($2.7 per acre). Average yield per acre was 8,760 pounds (tart) and 5.2 tons (sweet). The most frequently cited bird control methods were auditory scare devices, lethal shooting and visual scare devices. Producers frequently use a combination of available bird control techniques to maximize the number of birds deterred while minimizing costs. Lethal shooting and netting were the top two techniques scored as very effective, but netting was used at comparatively low rates (7% for both sweet and tart cherries) probably due to the high cost (Figures 4&5).

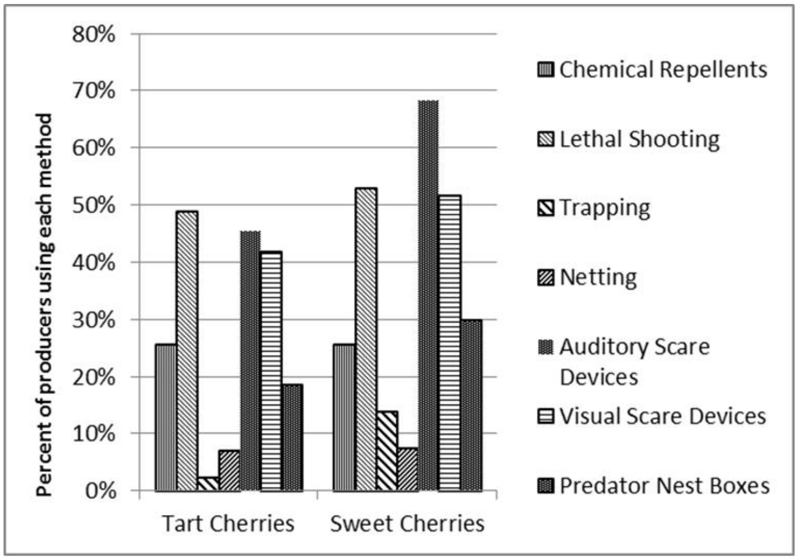

Figure 4. Percent of producers using each method of bird control.

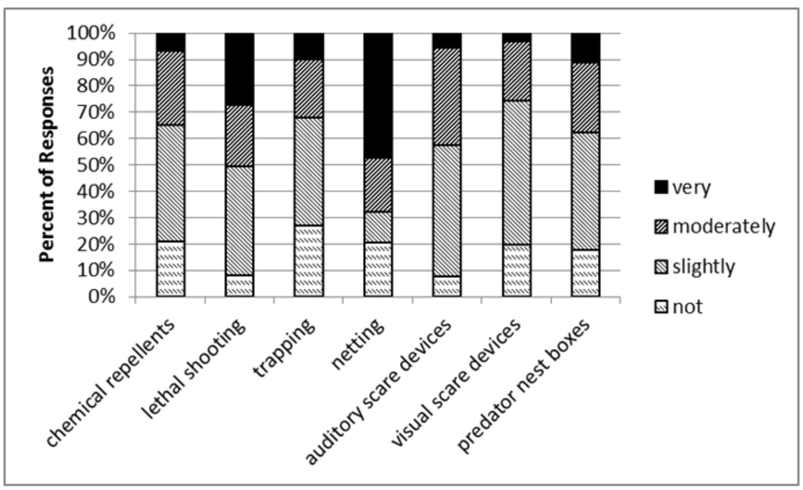

Figure 5. Effectiveness of bird control techniques

Producers of tart cherries may manage bird damage less frequently because tart cherries are less attractive to birds, because their value is relatively low, and because the vast majority of tart cherries are intended for processing so mildly damaged fruit is still marketable. In contrast, sweet cherries are highly attractive to birds, have a higher market value, and are mostly sold fresh so damage may cause fruit to be unmarketable.

Producers estimated their average yield loss due to bird damage was between 10.71% (tart cherries) and 14.16% (sweet cherries) in 2011 (Table 1). They estimated that their own use of bird control reduced yield lost by 17% and 22% (tart and sweet). A ban on bird control was predicted to increase yield loss by about 23% and 27%. These results indicate that current bird damage mitigation techniques are highly, but not completely, effective. The estimates were entered into the partial equilibrium model as low and high estimates of the percent reduction in yield resulting from reduced bird control.

The estimated yield lost with a total ban was not much larger than the expected loss when the producer alone stopped using bird management. This could indicate that producers expect control methods used by others will have a small effect on their own production, and are therefore unlikely to free ride on other producers' control efforts. The small difference may also suggest that producers have limited information about the effectiveness of their neighbors' control efforts, so they can't predict the effect of complete elimination of bird control. Additionally, a spillover effect may occur when nearby operations use nonlethal bird control techniques. Birds deterred from one farm may simply go to a neighboring farm, increasing the density of birds on those farms. Therefore, when a producer's neighbors stop using bird control techniques, the producer may actually see a decrease in bird activity on his/her farm.

Table 1. Percent yield lost with and without bird control

	Average Percent Yield Lost to Bird Damage	Average Percent Yield Lost with no Control By:		Percent Reduction in Damage Due to Bird Control		Percent Reduction in Yield Without Bird Control	
		Producer	Producer + Neighbors	Producer	Producer + Neighbors	Producer	Producer + Neighbors
Tart	10.71	26.27	31.11	59.24	65.58	17.43	22.84
Sweet	14.16	32.45	36.94	56.36	61.66	21.30	26.54

3.2 Supply Elasticities

Since no supply elasticities for cherries were available in the literature, elasticities were estimated using geometric distributed lags, generating a range from short run to long run. Data spanning thirty years of U.S. cherry production was obtained, providing the price and quantity produced each year for tart and sweet cherries separately. The data used for the model is annual data but, in the case of tree crops, it is more likely that the elasticities derived represent time frames longer than one year. Therefore, this analysis refers to each time *t* as a period, rather than a year. Regressions were performed for each type of cherry, defining the independent variable as quantity produced in the current year, and independent variables as price and quantity, both from the previous period:

$$Q_t = (1-\lambda)\alpha + \lambda Q_{t-1} + \beta\lambda P_{t-1}$$

Coefficients in the sweet cherry model were significant at the one percent level, indicating that sweet cherry producers are influenced by past prices when deciding how much to produce (Table 2). It is expected that previous periods' quantity produced would strongly influence the current period, since orchards take years to establish and producers can only expand or reduce bearing acreage by a small degree in a given period. This is supported by the significant coefficient for quantity.

The tart cherry regression did not return significant coefficients. This may be because tart cherry production is concentrated in one region (Michigan), so regional weather variations that impact production are not buffered by production in other regions as they are in sweet cherry production. For example, if Michigan experiences a drought it is unlikely that production in other regions will increase sufficiently to make up for the lost yield. Therefore, quantity produced varies significantly from year to year due to factors other than price.

Table 2. Regression results. Shaded variables are significant.

		Coefficients	SE	t Stat	P-value
Tart	Intercept	221.920813	94.7806	2.34142	0.02715
	Q_{t-1}	0.07333113	0.29861	0.24557	0.80794
	P_{t-1}	0.16678494	0.74005	0.22537	0.82345
Sweet	Intercept	-127404.12	37692.8	-3.3801	0.0023
	Q_{t-1}	0.5320344	0.12609	4.21941	0.00026
	P_{t-1}	138.426548	23.4206	5.91047	3.1E-06

Elasticities were calculated by multiplying the impact factor ($\beta\lambda$ in t+1) by the ratio of price to quantity in the previous period. For sweet cherries the quantity produced in period *t* was 375,625 tons at $1,350 per ton. Iterations on the regression equation were carried out at this price and simultaneously at price $1,351 until the supply elasticity began to converge (Table 3). A long run supply elasticity of 3.14 emerged after twelve iterations. Notably, supply is only inelastic in the first period, quickly becoming very elastic in subsequent periods.

Table 3. Derivation of short and long run supply elasticities for sweet cherries.

t	P=$1350 Quantity Produced 375,625	P=$1351 Quantity Produced 375,625	Impact Multiplier	Elasticity
t+1	259,317	259,456	138.43	0.72
t+2	197,437	197,649	212.07	1.45
t+3	164,515	164,766	251.26	2.06
t+4	146,999	147,272	272.10	2.50
t+5	137,680	137,964	283.20	2.78
t+6	132,722	133,012	289.10	2.94
t+7	130,085	130,377	292.24	3.03
t+8	128,681	128,975	293.91	3.08
t+9	127,935	128,229	294.79	3.11
t+10	127,537	127,833	295.27	3.13
t+11	127,326	127,621	295.52	3.13
t+12	127,214	127,509	295.65	3.14

Tart cherries had an initial quantity of 320.5 million pounds at 19.7 cents per pound. The very small coefficient on price in the regression indicates that quantity produced is not dependent on past prices, resulting in an elasticity of zero that does not increase over time (Table 4). Although there must be a long run price elasticity that is greater than zero, this model does not provide those estimates. Therefore, welfare impacts could only be analyzed in the short run.

Table 4. Derivation of short and long run supply elasticities for tart cherries.

	P=$0.197	P=$1.197		
	Quantity Produced			
t	320.5	320.5	Impact Multiplier	Elasticity
t+1	245.5	245.6	0.167	0.000
t+2	240.0	240.1	0.179	0.000
t+3	239.5	239.7	0.180	0.000

The elasticities derived for sweet cherries suggest that supply is only inelastic in the first period and becomes elastic in subsequent periods. It is unlikely that fixed costs become variable costs in the space of one year in tree fruit production, because trees require several years of growth before they begin producing fruit. Establishment of orchards is a long-term investment that cannot be easily reduced or expanded in one year. Although the elasticities were derived from annual data, it is more likely that one period represents several years rather than one year. A period could be considered to be the time required to increase production given an increase in price, probably around five to ten years, which is the average time between the planting of young trees and their maturity into fruit-bearing trees.

3.3 Welfare Analysis

A change in marginal cost implies a shift in the supply curve which affects production, market price, and consumer and producer surplus. The magnitude of these effects depends in part on the elasticities of the supply and demand curve. Demand for both sweet and tart cherries is relatively stable, so it was assumed not to change in this analysis. Supply will become increasingly elastic over time, meaning the supply curve will intersect demand at decreasing prices. In this analysis, consumers are the intermediaries between growers and households; the buyers that interact directly with growers. They include processing facilities, food distributors, and retailers.

Changes in producer and consumer surplus due to a ban on bird control methods were calculated using high and low estimates of yield loss provided by producers for both types of cherries. The change in marginal cost was calculated using information about the cost-effectiveness of bird control techniques and the additional damage producers expected to see in their crops if no bird management was used. The changes in consumer and producer surplus were calculated for each time frame using a constant demand curve, but allowing the supply curve to become more elastic. A new supply curve was derived from the original supply curve for each time frame (elasticity) for both high and low estimates of a change in bird control. Surpluses were calculated for each supply curve and compared with the original to determine the effect of reduced bird control. Supply curves were assumed to be perfectly inelastic in the first period that bird control is not used, meaning that the change in producer surplus is equal to the change in total revenue during that period. Because demand is inelastic for both varieties of cherries, the changes in producer surplus are positive and the changes in consumer surplus are negative in each time frame. As the supply elasticity converges to the long run elasticity, the changes in producer and consumer surplus between the original situation with bird control and the new situation without bird control decreases. This is due to the decreasing differences between elasticities as time frames increase, and the accompanying smaller decreases in price changes.

The decrease in total surplus for sweet cherries ranged from $153 million to $198 million in the short run, and $23 million to $31 million in the long run (Tables 5&6). Producer surplus increases without bird control because the demand curve is inelastic at the original equilibrium point (although not necessarily at the new equilibrium points), so the increase in price is proportionately greater than the decrease in production. This means that producers would actually benefit from total elimination of bird control. However, this is only true when all producers are not using bird control. If a few growers are using bird control, their lower costs will allow them to sell at lower prices, and the competitive nature of the market will incentivize other growers to find some way to lower their own costs (likely by adopting bird control practices themselves) so they can compete. In this way, the majority of producers will practice bird management, thereby decreasing prices and benefiting consumers.

Consumer surplus does not change in the original situation with current bird control practices because the supply curves representing the various time frames rotate through the current equilibrium point. Price and quantity do not change, so consumer surplus remains constant and producer surplus decreases as supply elasticity increases. Without bird control, consumer surplus decreases at a decreasing rate over time frames as price and quantity converge on the new equilibrium point.

Table 5. Changes in consumer and producer surplus using a low estimate of yield loss.

Sweet Cherries	ΔMC	164.28										
	E_D	-0.558		With Bird Control			Without Bird Control					
Time Frame	Quantity	Price	E_S	CS	PS	TS	CS	PS	TS	ΔCS	ΔPS	ΔTS
Short Run	241,380	2,717.67	0.00	540,552,774	603,256,896	1,143,809,670	334,777,847	655,990,464	990,768,311	-205,774,927	52,733,568	-153,041,359
	274,552	2,336.46	0.72	540,552,774	385,889,587	926,442,362	433,115,868	400,073,571	833,189,439	-107,436,906	14,183,984	-93,252,922
	285,579	2,209.75	1.45	540,552,774	208,007,965	748,560,739	468,603,720	229,133,343	697,737,064	-71,949,054	21,125,378	-50,823,676
	290,350	2,154.92	2.06	540,552,774	146,293,754	686,846,529	484,392,696	166,581,192	650,973,888	-56,160,078	20,287,438	-35,872,640
	292,645	2,128.55	2.50	540,552,774	120,703,316	661,256,090	492,079,594	139,623,060	631,702,654	-48,473,180	18,919,744	-29,553,437
	293,804	2,115.22	2.78	540,552,774	108,623,782	649,176,557	495,987,032	126,647,854	622,634,886	-44,565,743	18,024,072	-26,541,671
	294,405	2,108.32	2.94	540,552,774	102,574,796	643,127,570	498,016,993	120,084,628	618,101,621	-42,535,782	17,509,832	-25,025,950
	294,720	2,104.70	3.03	540,552,774	99,456,085	640,008,859	499,083,530	116,682,894	615,766,424	-41,469,244	17,226,809	-24,242,435
	294,886	2,102.79	3.08	540,552,774	97,823,978	638,376,752	499,647,207	114,897,711	614,544,917	-40,905,567	17,073,733	-23,831,834
	294,975	2,101.77	3.11	540,552,774	96,963,178	637,515,952	499,946,047	113,954,787	613,900,834	-40,606,727	16,991,609	-23,615,118
	295,021	2,101.24	3.13	540,552,774	96,507,314	637,060,089	500,104,742	113,455,041	613,559,783	-40,448,032	16,947,727	-23,500,305
	295,046	2,100.95	3.13	540,552,774	96,265,374	636,818,148	500,189,090	113,189,700	613,378,790	-40,363,684	16,924,326	-23,439,358
Long Run	295,060	2,100.80	3.14	540,552,774	96,136,821	636,689,595	500,233,942	113,048,683	613,282,625	-40,318,832	16,911,862	-23,406,970

Table 6. Changes in consumer and producer surplus using a high estimate of yield loss.

Sweet Cherries	ΔMC	221.04										
	E_D	-0.558		With Bird Control			Without Bird Control					
Time Frame	Quantity	Price	E_S	CS	PS	TS	CS	PS	TS	ΔCS	ΔPS	ΔTS
Short Run	225,325	2,902.16	0.00	540,552,774	603,256,896	1,143,809,670	291,724,624	653,930,614	945,655,238	-248,828,150	50,673,718	-198,154,432
	265,182	2,444.15	0.72	540,552,774	385,889,587	926,442,362	404,055,000	401,541,027	805,596,027	-136,497,774	15,651,440	-120,846,334
	279,049	2,284.78	1.45	540,552,774	208,007,965	748,560,739	447,420,432	234,363,613	681,784,045	-93,132,342	26,355,647	-66,776,695
	285,151	2,214.67	2.06	540,552,774	146,293,754	686,846,529	467,200,301	172,116,816	639,317,117	-73,352,473	25,823,062	-47,529,412
	288,107	2,180.69	2.50	540,552,774	120,703,316	661,256,090	476,938,990	144,969,431	621,908,420	-63,613,785	24,266,115	-39,347,670
	289,607	2,163.46	2.78	540,552,774	108,623,782	649,176,557	481,916,782	131,823,056	613,739,839	-58,635,992	23,199,274	-35,436,718
	290,385	2,154.51	2.94	540,552,774	102,574,796	643,127,570	484,510,098	125,152,031	609,662,129	-56,042,676	22,577,234	-33,465,442
	290,794	2,149.82	3.03	540,552,774	99,456,085	640,008,859	485,874,621	121,688,624	607,563,244	-54,678,154	22,232,539	-32,445,615
	291,010	2,147.34	3.08	540,552,774	97,823,978	638,376,752	486,596,342	119,869,464	606,465,806	-53,956,432	22,045,486	-31,910,946
	291,124	2,146.02	3.11	540,552,774	96,963,178	637,515,952	486,979,127	118,908,142	605,887,269	-53,573,647	21,944,964	-31,628,683
	291,185	2,145.32	3.13	540,552,774	96,507,314	637,060,089	487,182,445	118,398,518	605,580,963	-53,370,329	21,891,204	-31,479,125
	291,217	2,144.95	3.13	540,552,774	96,265,374	636,818,148	487,290,522	118,127,897	605,418,419	-53,262,252	21,862,523	-31,399,729
Long Run	291,234	2,144.76	3.14	540,552,774	96,136,821	636,689,595	487,347,996	117,984,063	605,332,058	-53,204,779	21,847,242	-31,357,537

The change in total surplus for tart cherries was less substantial (Tables 7&8). Total surplus decreased by between $13 and $18 million and the marginal cost of production increased to 4 to 6 cents per pound. Similar to the case of sweet cherries, producers gain and consumers lose due to the inelastic demand. Welfare analysis could only be performed for the very short run because the geometric distributed lag model did not produce longer run elasticities.

Table 7. Tart Cherries: Changes in producer and consumer surplus using a low estimate of yield loss.

ΔMC	0.043										
E_D	-0.381		With Bird Control			Without Bird Control					
Quantity	Price	E_S	CS	PS	TS	CS	PS	TS	ΔCS	ΔPS	ΔTS
169,271,580	0.44	0.00	80,708,661	61,500,000	142,208,661	55,027,593	74,010,996	129,038,589	-25,681,068	12,510,996	-13,170,072

Table 8. Tart Cherries: Changes in producer and consumer surplus using a high estimate of yield loss.

ΔMC	0.061										
E_D	-0.381		With Bird Control			Without Bird Control					
Quantity	Price	E_S	CS	PS	TS	CS	PS	TS	ΔCS	ΔPS	ΔTS
158,170,139	0.48	0.00	80,708,661	61,500,000	142,208,661	48,046,462	75,901,534	123,947,996	-32,662,199	14,401,534	-18,260,665

The decrease in total surplus resulting from a total ban on bird control methods is equivalent to the gain in total surplus generated from the use of bird management. In other words, controlling bird damage in all cherry production increases total surplus by a range of \$166 to \$216 million in the short run, \$23 to \$31 million in the long run (without long run estimates for tart cherries). Consumers benefit from the use of bird control, while producers actually lose. This is consistent with economic theory under the assumption of perfect competition, which states that, in the very long run, producer surplus decreases to zero due to incentives for new producers to enter the market and existing producers to take on new costs to out-compete other producers as long as there is a positive producer surplus to be exploited.

Chapter Four: Conclusions

4.1 Summary of Findings

Cherries have become an increasingly important fruit crop for the states of Michigan, Oregon, California, Washington, and New York that collectively produce the vast majority of cherries nationwide. Additionally, the U.S. is one of the main exporters of cherries in the world, influencing the world price and impacting international markets.

Birds are a known cause of crop damage and loss, and to date there is no single effective, inexpensive, and humane method for managing birds. Producers often resort to using multiple methods, increasing their costs while still losing over 10% of their crop to birds. However, without any bird control producers estimate that the amount of their crop lost to birds would increase substantially, to a minimum of 25% of their crops.

Supply elasticities were derived from available production data, providing a range of elasticities from short run to long run for sweet cherries. Production of sweet cherries is heavily dependent on price and quantity produced in previous years, resulting in a very elastic long run supply curve. Production of tart cherries was not correlated with price or production in previous years, resulting in a single supply elasticity of zero. This implies that variations in quantity produced may not be related to variations in price, but are influenced or overshadowed by other factors such as weather.

Using estimates of the change in yield loss from producers, the change in the marginal cost of sweet and tart cherry production was calculated. Costs increased for both sweet and tart cherry producers, shifting the supply curve to the left and resulting in a sharp increase in price. The increasing elasticity of the supply curve causes the price to drop and output to increase in subsequent time periods. The price increases compared to the baseline are proportionately larger than the reduction in output because demand is inelastic, causing an increase in producer surplus and a loss in consumer surplus. Overall, the total cost of a bird control ban to society would be between $166 and $216 million immediately, and at least $23 to $31 million in the long run. Conversely, bird management in cherry production can be said to benefit the U.S. by the same amount. Since producers continue to lose a significant portion of their crop to birds with current management techniques, benefits to consumers could be increased with improved methods for control. Producers may lose, but the analysis demonstrates that consumer benefits of bird control are greater than producer losses, suggesting that total surplus could be increased with lower yield losses.

The findings of this study may be used to inform decisions regarding new regulations for bird control by providing policymakers with information about the value of current bird management, as well as possible benefits from improved methods. Some techniques are controversial and policymakers, producers, researchers and the public can benefit from accurate information about the value of management when considering possible restrictions. Additionally, policymakers may take this information into consideration when allocating resources to research projects. The value of more effective control techniques could be used when estimating the rate of return of new research for bird control.

4.2 Limitations

Estimates of the effect of bird damage on cherry crops were provided by individual producers via a survey. Producers may not be able to accurately estimate damage sustained to their crops, or damage avoided by using bird control, because they might not have experienced production without bird damage. Therefore, they may not know what the potential yield would be with no bird damage. Also, it is probably difficult for producers to estimate what their yield could be if neighboring operations changed bird control practices since they might have incomplete information about their neighbors' current bird control practices. High and low estimates were obtained by asking producers to estimate damage avoided in two scenarios: one in which no producers in their area are using bird management, and an alternative where only the individual producer is not using bird management. The results of these two questions allowed a range estimates to be constructed. However, producers may have under- or overestimated current or potential damage and the range of results does not necessarily reflect this.

Additionally, the supply elasticities derived for tart cherries limit the analysis to the short run because of the insignificant regression results they are based on. The analysis accurately captures the effects of the initial supply shock but does not provide any information about the longer run effects of a change in bird control practices. Consequently, the analysis for tart cherries is of limited value.

4.3 Future Research

Estimation of supply elasticities, especially for tart cherries, could be improved by using an adaptive expectations model. This type of model might more accurately capture the effect of past prices on current production, resulting in more credible supply elasticities. Additionally, the partial equilibrium model could be modified to include the effects of exports on the demand curve. While cherry imports are negligible, exports make up a substantial portion of total cherry production, about 16%. The model used in this analysis assumed that U.S. and international consumers have the same demand curve, which may not be true. International consumers are likely to have different preferences due to variation across cultures, and face a different set of substitutes. Different demand elasticities could be used for domestic and foreign consumers to better elucidate the welfare effects of changes in bird management on domestic consumers compared with foreign consumers. Demand elasticity could also be allowed to change with various time frames, if appropriate, as supply elasticities do. Additionally, a sensitivity analysis for changes in surplus could be performed using a range of demand elasticities.

Finally, prices used in this analysis are those faced by intermediate consumers, i.e. processing facilities and retailers. This information could be used to estimate macroeconomic impacts such as job creation. It would also be useful to extend this analysis to the final consumer to determine how much of the savings from bird management is seen in individual households.

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