THESIS

BIRD AND RODENT PEST CONTROL IN SELECT CALIFORNIA CROPS:

ECONOMIC CONTRIBUTIONS, IMPACTS, AND BENEFITS

Submitted by

Jennifer Schein Dobb

Department of Agricultural & Resource Economics

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2014

Master's Committee:

Advisor: John Loomis

Robert Kling
Stephanie Shwiff
Aaron Anderson

ABSTRACT

BIRD AND RODENT PEST CONTROL IN SELECT CALIFORNIA CROPS: ECONOMIC CONTRIBUTIONS, IMPACTS, AND BENEFITS

Although numerous factors affect agriculture production, significant yield and quality losses of crops have been attributed to wildlife, insects, and diseases; collectively known as pests. To mitigate pest activity agricultural producers utilize a variety of control tools and techniques including rodenticides, trapping, exclusion, and chemical aversion (Sexton et al., 2007); causing integrated pest management to become an integral part of modern agricultural production. Although crop savings is arguably the most important contribution of pest control, relatively few studies have attempted to quantify prevented crop loss and the economic impacts of these cost savings.

This study found that current California control practices as applied to alfalfa, almonds, avocados, carrots, cherries, citrus, grapes, lettuce, melons, peaches, pistachios, rice, strawberries, tomatoes, and walnuts were effective at mitigating crop loss which had the potential to significantly restrict the domestic supply of these agricultural commodities. These practices were shown to lower wholesale prices and were estimated to prevent multi-million dollar losses to California growers, and multi-billion dollar losses to consumers nationwide.

In addition to the direct benefits realized through these crop savings, the production and sale of these additional yields further stimulates economic activity within the state. Modeling the

forward and backward linakages between California suppliers and consumers enabled monetary flows in secondary markets to be quantified, providing a more conclusive estimate of the total benefits of bird and rodent control in California. This study found that expenditures related to the production of additional yields protected from rodent damage contributed $1.7 billion to California's economy and supported 23,000 jobs, with farm revenue earned on these yields supporting another 11,000 California jobs and contributing nearly $951 millionto the state's economy. Findings from this study also estimated that the production of yields protected from bird damage were estimated to contribute $1.39 billion to the state's economy and supported more than 20,000 jobs, with farm revenue earned on these yields supporting another 6,775 jobs and contributing another $565 million to California's economy.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Chapter one is broken into six sections and provides an overview of the purpose and motivation behind this study. This chapter begins with an overview of California's Agriculture sector, providing statistics on the importance of production within California. Section two discusses agricultural pest damage and summarizes key findings from past studies. The third section traces the history of federal and state regulations governing pesticide use and the financial costs these regulations impose on California growers. Sections four and five discuss the micro and macroeconomic theories of agricultural pest damage, and finally section six outlines the rest of the thesis.

1.1: California Agriculture

The Agriculture sector is a major component of the US economy and the driving force behind US exports, and California leads the country in agricultural output. In 2010, the state's agricultural production was valued at $37.5 billion. These cash receipts exceeded any other state's production by $14.3 billion, and accounted for 16% of national crop revenue and 7% of U.S. revenue from livestock and livestock products. The 81,700 farms operating in California encompass 25.4 million acres, and directly employed 380,850 California workers on average in 2010 (CDFA 2011, CalEDD 2011).

Over the years California has become synonymous with high quality agricultural goods and much of its success can be attributed to its diversity and high concentration of perennial and specialty crops. California agriculture produces more than 400 commodities, grows over 200 different crops, and accounts for nearly half of all fruits, nuts, and vegetables grown in the U.S

(CDFA 2011). The state remains the sole US producer of almonds, raisins, walnuts, pistachios, prunes, and nectarines and is responsible for more than 80 percent the domestic supply of avocados, strawberries, wine and table grapes, lemons, plums, broccoli, celery, garlic, lettuce, processing tomatoes, and cauliflower (Lee, 2002).

In addition to the farm revenue generated from the sale of these crops, agriculture production stimulates the state's economy through the goods and services these growers consume and the increased consumption by input suppliers. A 2005 report examining the economic impacts of wine and vineyards in Napa County estimated that the sale of grapes grown in the county was valued in excess of $412 million. These vineyards also created economic impacts through the $160 million they spent within the county on input materials and local wages, and by supporting Napa Valley's multi-billion dollar wine industry. This study estimated that the full economic impact of the county's wine and vineyard sector was approximately $9.5 billion (MKF, 2005).

1.2: Pest Damage

Production decisions of agricultural commodities are heavily influenced by market prices and the quality and quantity of crop yields. In addition to weather, significant yield and quality losses of crops have been attributed to wildlife, insects, and diseases. The damages incurred by agricultural producers from wildlife are diverse and known to be caused by birds, rodents, and ungulates. In addition to consuming ripe crops, there have been frequent reports of structural damage to plants caused by rodents girdling trees and feeding on roots, pecking activities of birds damaging ripening fruits and nuts, and extensive damage to fences and field equipment through the rooting behavior of feral swine (Crase et al., 1976; Johnson and Timm, 1987; Hueth et al., 1997; Berge et al., 2007; Kreith, 2007).

Numerous studies have examined agricultural pest damage, estimating that crop and property losses cost the agriculture industry millions of dollars each year. In the United States, total losses from all pests have been previously estimated to be 1/3 of total potential production before harvest, and nearly 10 percent after harvest (OTA, 1979). The National Agricultural Statistics Service estimated that vertebrate pest damage to field crops and fruit/nut crops nationwide were $751 million and $177 million respectively (NASS, 2002). In California, vertebrate pests were estimated to have caused $55 million in crop damage (Clark, 1976); birds were estimated to cost the state's pistachio industry over $3.7 million (Salmon, Crabb, and Marsh, 1986), and ground squirrels were found to have caused between $10 and $16 million worth of crop damage (Marsh, 1998). A recent economic analysis of the direct and indirect effects of bird and rodent damage to 22 major crops and commodities in 10 California counties found that total revenue lost ranged from $168 to $504 million annually, causing the loss of 2,100 - 6,300 jobs in these regions (Shwiff et al., 2009).

The substantial financial losses associated with vertebrate pests have caused integrated pest management to become a growing component of agricultural production. Many growers now utilize a variety of control tools and techniques including rodenticides and trapping, exclusion, and chemical aversion to reduce pest activity (Sexton et al., 2007). The widespread adoption of these control methods has given rise to a multi-billion dollar industry. The EPA estimated the agriculture sector spends $8 billion annually on pesticides; and direct spending on bird and rodent pest control in 10 California counties was estimated to generate $37.8 million in revenue, and create 692 jobs annually (EPA, 2011., Shwiff et al., 2009).

Probably the most significant economic contribution these abatement tools provide comes from the crop loss they prevent. Previous research has shown that each dollar invested in pesticides returns approximately $4 in protected crops (Headley, 1968., Pimentel et al., 1992., Pimental, 1997). In the absence of pest control, crop loss and property damage would rise, reducing agricultural output and increasing industry production costs. These changes in agricultural production would reduce economic activity in the agricultural sector, and create a ripple effect that would reduce employment and revenue statewide.

1.3: Regulations

Any substance or device designed to prevent, destroy, repel, or mitigate pest activity can be classified as a pesticide. These abatement tools are commonly referred to by the pest they target, and include organic, inorganic, synthetic, and biological agents (EPA-a). Although the use of pesticides reduces damage, many control measures have been shown to produce harmful biological and ecological effects. Growing concern for adverse human health and environmental effects, and harm to non-target species has led to the regulation and prohibition of many control methods.

The first federal regulations of pesticides in the United States were enacted in the early 1900's, and focused on the efficacy of products rather than on their use. To protect growers from fraudulent products congress passed the Federal Food and Drugs Act of 1906 and the Federal Insecticide Act of 1910, outlawing the sale of adulterated or mislabeled products. These laws were superseded by the Federal Food, Drug, and Cosmetic Act (FFDCA) of 1937, which authorized the Food and Drug Administration (FDA) to set limits or tolerances for chemicals in food to protect public health; and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947, which established labeling provisions and procedures for registering pesticides with the U.S. Department of Agriculture (USDA) (Toth, 1996).

In 1970 the Environmental Protection Agency (EPA) was created as part of the Executive Branch of the federal government under President Nixon's Administrative Reorganization Plan, and charged with the administering FIFRA. Two years later congress passed the Federal Environmental Pesticide Control Act (FEPCA) of 1972, which transferred administration authority to the EPA and essentially rewrote FIFRA (Wade, 1985). Often referred to as FIFRA-1972, the FEPCA amendments provided the EPA with the authority to establish tolerances for pesticide residues on raw agricultural commodities and processed food during the registration process, and relinquished enforcement of these tolerances to the FDA and USDA.

Since the seventies, FIFRA and FFDCA have been amended numerous times to more effectively regulate the distribution, sale, and use of pesticides. Recent changes stemmed from the Food Quality Protection Act (FQPA) and the Pesticide Registration Improvement Act (PRIA) which required the EPA to reassess all registered pesticides, and motivated the streamlining of the registration process. The FQPA in particular was a landmark piece of pesticide legislation because it acknowledged the need to mitigate the cumulative effects of long-term exposure to pesticides by revising tolerances to ensure with “reasonable certainty” that these practices did not cause harm (Esworthy, 2010).

Although amended FIFRA and FFDCA are the two major statutes governing pesticide use, pesticides are also subject to federal and state environmental and public health mandates which extend protection to other species and ensure water and skin exposure is not harmful to humans. These additional federal regulations stem from the Endangered Species Act, the Migratory Bird Act, the Clean Water Act, the Safe Drinking Water Act, the Occupational Safety and Health Act, and the Food, Agriculture, Conservation, and Trade Act (EPA-b) and outline the minimum standards which all U.S. pesticide users and producers must comply with. Although federal law takes precedent over those enacted at lower levels, states have the ability to adopt and enforce more protective standards through the product registration process (CalEPA, 2011). If a product fails to comply with a state's safety criteria, they have the authority to deny registration; thereby prohibiting their sale, possession, or use within the state.

California has a reputation of being in the forefront of progressive legislation designed to protect the environment and its citizens. The first pesticide-related laws in California date back to the early 1900's and focused on protecting consumers from ineffective and mislabeled products and was enforced by a several state boards and county commissioners. To ensure quality and protect against consumer fraud a 1901 statute required all dealers of an arsenic-based insecticide known as Paris green to submit product information and samples to the University of California (UC) agricultural experiment station so manufacturers' claims could be validated.

In 1911 state legislation parallel to the Federal Insecticide Act was passed and required all manufacturers, importers and dealers of insecticides and fungicides to register their products for a $1 fee with UC. This registration process required producers and dealers to submit product information describing the brand name, pounds in each package, name and address of manufacturer, and a chemical analysis showing "the percentage of each substance claimed to have insecticidal value, the form in which each is present and the materials from which derived, and the percentage of inert ingredients" (CalEPA, 2011). These provisions were designed to enable users to determine the insecticidal value of products and stop producers from selling "secret remedies" with fictitious ingredients.

In1921, California passed the Economic Poison Act, which was another monumental piece of pesticide-related legislation. The Economic Poison Act consolidated and transferred regulatory authority to the California Department of Agriculture (later known as the California Department of Food and Agriculture) and was the first comprehensive law regulating the manufacturing and sale of insecticides, fungicides, and rodent and weed poisons (CalEPA, 2011). During this period, there were a growing number of newly developed synthetic organic pesticides introduced to the market. Although famers did not fully understand what or how these chemicals worked, their acceptance and use became widespread.

As pesticide use by farmers increased, the benefits and unintended consequences of their use became evident. Although many pesticides proved to improve plant health and increase crop yield, their use was also associated with damage to non-target crops and caused injury and death to humans, livestock, and wildlife. By the late 1940's there were numerous highly publicized reports of illnesses linked to pesticide residuals, including major cities attributing high levels of arsenic in fruit as the cause of abnormally high occurrences of seizures (CalEPA, 2011). Growing concern for human and animal health led policy makers to realize the need for pesticide legislation that regulated the efficacy and safety of these products.

In 1949, the state enacted the first laws which regulated pesticide handling and imposed restrictions on pesticides known to have a high likelihood of causing harm to people, crops, or the environment (CalEPA, 2011). Since then, California has remained committed to protecting the public and environment through the development and adoption of least-toxic pest management practices. By taking an increasingly science-based approach towards policy development, California has been successful in establishing the most comprehensive state pesticide regulation program in the nation and built a reputation as a leader in research and regulatory decision making.

The state's pesticide regulatory authority was transferred to the California Environmental Protection Agency (CalEPA) in 1991 when new legislation united the Air Resources Board (ARB), State Water Resources Control Board, Integrated Waste Management Board (IWMB), Department of Toxic Substances Control (DTSC), and Office of Environmental Health Hazard Assessment (OEHHA) into a single cabinet-level agency. Since then, the pesticide regulation program has since been managed by CalEPA's Department of Pesticide Regulation (DPR). DPR's mission is to protect human health and the environment by regulating the sale and use of pesticides, and by fostering reduced-risk pest management (CalEPA, 2011). The regulatory activities of DPR are performed by the seven branches of its Pesticide Program Division: Pesticide Enforcement, Environmental Monitoring, Pest Management and Licensing, Pesticide Registration, Medical Toxicology, Product Compliance, and Worker Health and Safety. The integrated work between these branches covers every aspect of California pesticide use and sales, monitoring pesticides from the time they are applied in the fields until the agriculture products they're used on are consumed by the public.

DPR's primary responsibility is the scientific evaluation and registration of pesticide products. Although the EPA at both the state and federal levels has made efforts to streamline their registration processes, it can take upwards of 6 to 9 years and cost millions to register a single pesticide (Toth, 1996). Before a pesticide can be distributed, sold, or used in California it must be registered with DPR, which requires it to be registered with the U.S. Environmental Protection Agency first. After receiving a registration application for a new product, the DPR thoroughly examines the ingredients of a pesticide product, the site or crop on which it is to be used, the amount and frequency and timing of use, and its potential effect on human health and the environment using the guidelines of the Food and Agricultural Code (FAC) to ensure that it is effective and will not harm human health or the environment when used according to label directions (CalEPA, 2011). Once a pesticide is registered in California, manufacturers are subject to an annual pesticide registration fee of $750 per product per year to continue the sale, use, and distribution of their product.

Those wishing to possess and use pesticides in California are also subject to strict regulations and costly fees. In addition to business licenses there are three primary types of licenses or certificates issued to individuals who buy, sell, or use pesticides in California. Any person who offers a recommendation on the agricultural use, holds himself or herself as an authority on agricultural use or solicits services or sales of pesticides for agricultural use is required to obtain an Agricultural Pest Control Adviser License (PCA license). To earn a PCA license, applicants must have either completed a Bachelor's degree in agricultural science, biological science or pest management, or have completed 60 semester units of college-level curriculum, plus 24 months of experience as an assistant to a PCA (CalEPA, 2010-1). They must submit an application, provide proof of meeting the minimum educational and experience requirements, pay an application fee of $80 and pass the Laws, Regulations, and Basic Principles examination and at least one pest control category examination within one year at a cost of $50 per licensing exam. Once a license is obtained, licensees are required to pay a $140 renewal fee and accumulate at least 40 hours of approved continuing education every two years to maintain a valid license. PCA's must also pay $10 per year to register in their home county where they conduct business, plus an additional $5 per year to register in each additional county in the PCA wishes to conduct business (CalEPA, 2010-1). A 2006 survey of producers estimated that a citrus producer in Tulare County who holds a PCA license would spend $3,500 annually in fees, cost of travel to programs, and his time to maintain the license (Hamilton, 2007).

CalEPA also requires any individual applying or supervising the application of pesticides or is responsible for the safe and legal pesticide applications of a licensed pest control business, to obtain a Qualified Applicator License (QAL) (CalEPA, 2010-2). Like the PCA, applicants for this license must submit an application, pay an $80 application fee, and pass the Laws, Regulations, and Basic Principles examination and at least one pest control category examination within one year at a cost of $50 per licensing exam. To renew QAL's, license holders are required to accumulate a minimum of 20 hours of continuing education and pay a renewal fee of $120 every two years (CalEPA, 2010-2).

The other most common certification is a Qualified Applicator Certificate (QAC). QAC's are required by individuals not associated with a licensed pest control business who use or supervise pesticide application on land they do not own or lease. Of the three, this has the lowest requirements and costs. This certificate is also required for anyone in the business of landscape maintenance who performs pest control that is incidental to such a business. Applicants for these certificates are required to submit an application, pay a $40 application fee, and pass the Laws, Regulations, and Basic Principles examination and at least one pest control category examination within one year at a cost of $50 per licensing exam. To renew a QAC, license holders are required to accumulate a minimum of 20 hours of continuing education and pay a renewal fee of $60 every two years (CalEPA, 2010-3).

Although regulations have a positive impact on society by reducing the risk of unintended harm to humans and the environment, compliance with the more than 25 separate state and federal laws governing the use of resources used in agricultural production was reported to add nearly $1 billion to California growers' costs (Hurely et al., 2006). A 2006 analysis of the regulatory effects on California specialty crops found that in just five years the direct cost of compliance with certain environmental regulations had more than doubled, and the amount of time growers devoted towards regulatory issues had increased by 40 percent (Hurely et al., 2006). California producers surveyed in this study indicated that the local, state and federal regulations they were subject to had become increasingly complex and costly, were littered with duplications between regulatory agencies, and are believed to have had a negative effect on their ability to effectively manage their farms (Hurely et al., 2006).

A 2004 study analyzing the future outlook for California agriculture cited increased regulation as a relatively new driver among 20 major factors affecting the future of California agriculture, but a factor that will have increasingly negative impacts on the state's competitiveness at the national scale (Johnston and McCalla, 2004). Recent mandates imposed on California producers have reduced the competitiveness of crops grown within the state by prohibiting producers from using many cost effective inputs with long proven efficacy. In many cases, these regulations have prohibited California producers from continuing to use agricultural practices commonly used by their domestic and international counterparts.

Several studies have examined the impacts of involuntary pesticide substitution on production of select California crops, focusing primarily on substitutions triggered by the prohibition of chemical pesticides. A study assessing the impacts of a methyl bromide (MBr) ban on California's strawberry industry estimated that prohibiting growers from continuing to use MBr would cause industry revenue to decline by 6-17% (Carter et al., 2005). Even though a substitute chemical was determined to be equally effective as methyl bromide at reducing pest damage, substituting two different chemicals for MBr was shown to increase control costs up to $300 per acre (Carter et al. 2004). A Salinas Valley lettuce study determined that switching from commonly used organophosphate and carbonate compounds, which were put under review by the Food Quality Protection Act, to biologically based pesticides would increase production costs by $40-$50 per acre (Hamilton, 2001).

Results from Hurley's analysis of regulatory effects on select California crops found that the state's increasingly prohibitive regulatory environment had caused more than 45% of producers to consider leaving agriculture, and that producers would rather exit the industry than relocate operations outside of California. These producers were also shown to be more likely to exit the industry, or prepare to exit the industry, than increase the size of their operation to realize benefits through economies of scale (Hurely et al., 2006). The willingness of California growers to abandon agricultural production within the state demonstrates how frustrated producers have become with agricultural policies, and illustrates how detrimental these regulations can be to farm profitability in California.

1.4: Microeconomic Effects of Reduced Crop Yield

Economic theory explains the tendency of competitive markets to move towards a market clearing equilibrium price where quantity supplied equals quantity demanded. This equilibrium illustrates the efficient allocation of resources, where resources are utilized in a way which maximizes the social net benefits that arise from their use. These social net benefits are the sum of benefits to producers and consumers, in excess of any expenditure incurred to produce or consume a good. When in equilibrium, the sum of these surpluses is maximized and any gains realized can only come at the other's expense.

For consumers, this is measured by the difference between the maximum price they are willing to pay for a product and the actual price they paid. Graphically, consumer surplus is represented by the area below the demand curve and above the market price. Producer surplus is the difference between the market price the producer receives for the good and the marginal cost to produce it, and represents the profit on the unit, plus any rents accruing to factors of production. Graphically, producer surplus is the area above the marginal cost or supply curve and below the market price.

Assuming markets for agricultural commodities are competitive and operating in equilibrium, with no externalities; current market prices and quantities are market clearing and maximize net social benefits. Figure 1 graphically represents a competitive agricultural market in equilibrium, where *P** and *Q** represent optimal market levels and *A* and *B* illustrates consumer and producer surplus.

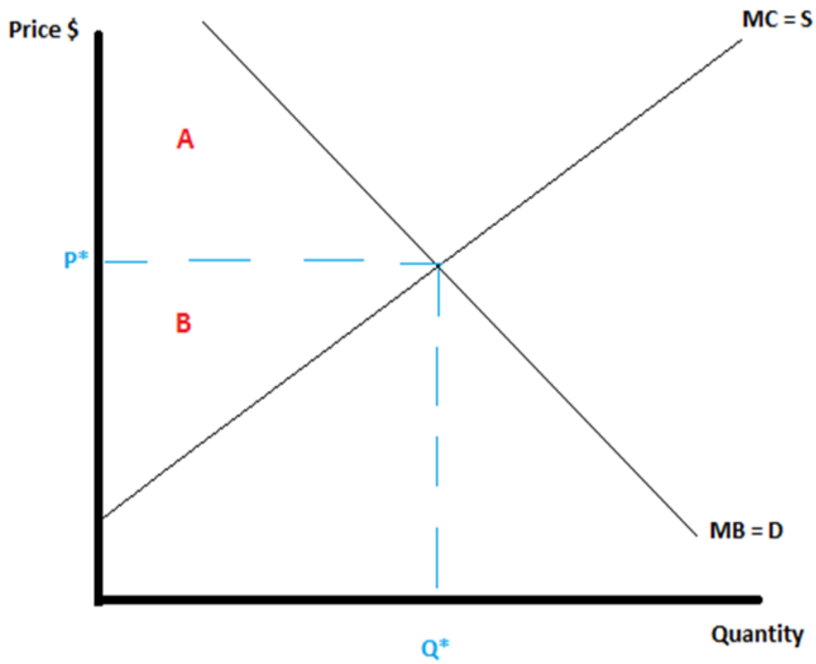

Figure 1: Competitive Agriculture market in Equilibrium

New regulations prohibiting the use of pest control would lead to a reallocation of resources used in agricultural production which would stimulate two distinct changes in the marginal cost functions of producers. First, a prohibition on pest control would eliminate input costs associated with control practices. Since producers would no longer use control practices as an input factor, producers' marginal cost curve would shift to the right by an amount equivalent to the eliminated pest control expenditures. Since the horizontal summation of individual marginal cost curves reflects market supply, shifts in at the firm level cause the market supply curve to shift.

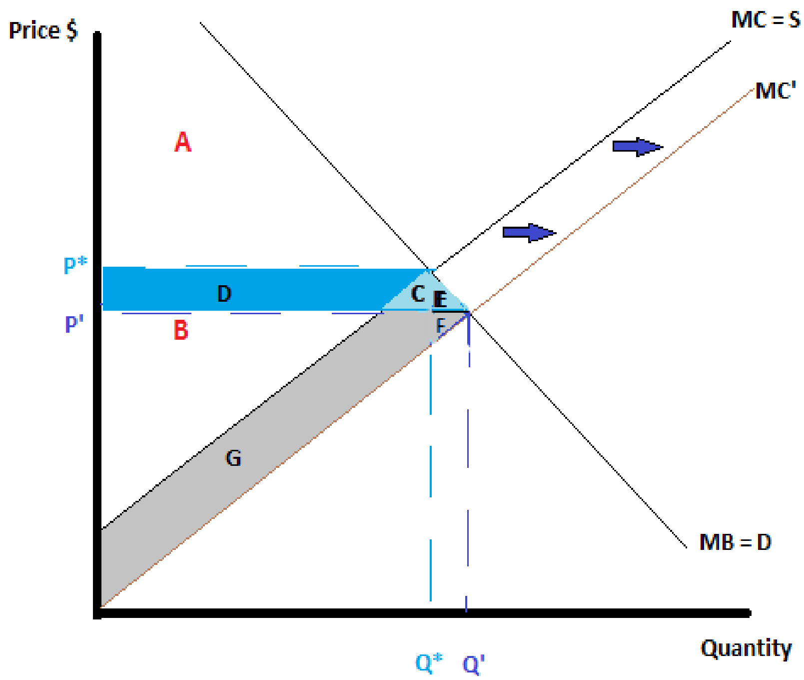

Figure 2: Competitive Agriculture Market when Pest Control is Prohibited

Figure 2 illustrates how reduced production costs stimulate production. This enables producers to supply a greater number of units to consumers at a lower price, increasing net benefits to everyone. The shift in supply reflecting a movement from *MC* to *MC'* increases social net benefits by the triangle *EF*. Consumer surplus increases through a transfer of *D* from producers, and by the new benefits reflected in triangle *CE*. Although producer surplus is transferred to consumers, producers gain by the cost savings reflected in *G* and by the new benefits captured in triangle *F*.

Although a pest control prohibition lowers input production costs, eliminating pest control practices would cause pest damage to rise. Increased crop and property damage increases the marginal cost of producing agricultural products, causing the marginal cost curve for agricultural goods to shift left as yield per acre falls. Since producers could not eliminate pest control expenditures without incurring greater losses, the true result of a ban on pest control would cause the market supply to decrease. We could expect this second supply curve shift to be greater than the first, because agricultural producers would not control for pests if the cost to control exceed their private benefits. The new equilibrium would result in a lower quantity and higher prices, as illustrated in figure 3.

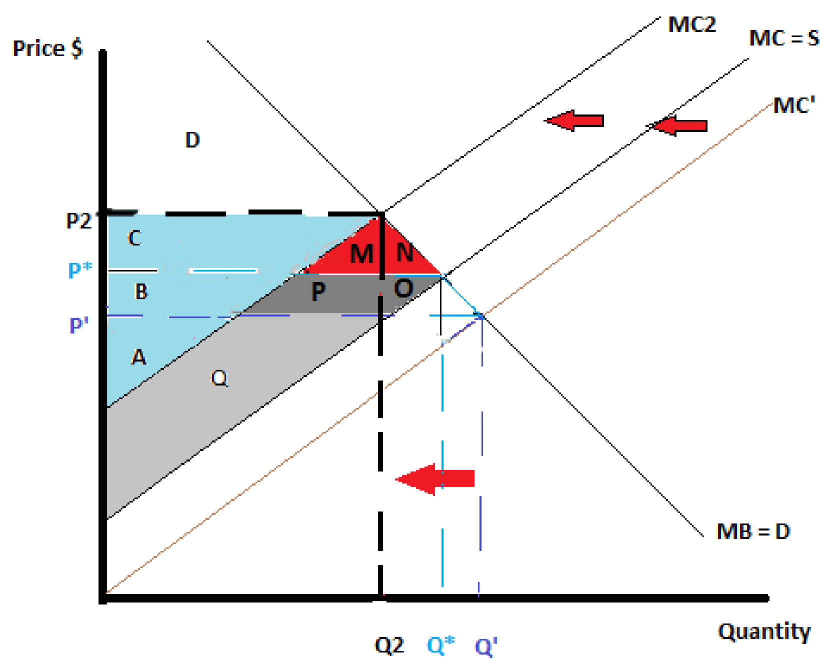

Figure 3: Competitive Agriculture Market with Increased Yield Loss

Reduced California crop yields resulting from additional regulations have the ability to affect the overall market outcome. As figure 3 illustrates, increased pest damage reduces productivity in the farm sector, causing the aggregated agricultural supply curve to shift inwards by the value of eliminated control costs, minus the market value of lost output. The higher cost associated with the consumption and production of agricultural goods makes both producers and consumers worse off, resulting in a loss of net social benefits equal to the area of *MNOPQ*.

The magnitude by which surpluses change depends on the responsiveness of producers and consumers to price changes. Economic theory uses price elasticities to measure how relatively small changes in price affect other economic variables. In this case, price elasticities of supply and demand are utilized to quantify the percent change in the quantities of agricultural commodities supplied and demanded resulting from a one percent change in their price. If the resulting change is estimated to be less than one in absolute value, agents are relatively less responsive to price changes and demand/supply for/of the good is referred to as inelastic. If the supply or demand for a good changes by more than 1 percent in response to a marginal change in price, the good is said to possess elastic supply/demand. The more elastic, or flat, the supply and demand curves are the smaller the surpluses will be relative to total revenues.

Although reduced supply will always have a positive effect on prices, whether these price changes translate into greater revenue for growers depends on the supply and demand elasticities of the crop. Crops with relatively inelastic supply in the short run would be expected to incur greater production losses because acreage could not be as easily increased to compensate for reduced yield per acre. This scarcity leads to higher prices which consumers are not always willing and able to pay. If consumers' demand for the product is relatively inelastic, the demand for the product will be relatively unaffected and producers' revenue will increase. If consumers' demand is more responsive to a price change, the higher prices cause demand and revenue for the crop to fall.

1.5: Macroeconomic Effects of Reduced Crop Yield

As discussed in the previous section, reduced crop yields resulting from the prohibition of pest control practices have the potential to significantly affect welfare distributions and market outcomes. In addition to these market effects, reduced crop yields would also generate macroeconomic effects that cause changes in the structure and performance of California's economy. Crop savings through current control practices enabled California crop production to contribute nearly $ 27.7 billion and 170,067 jobs to California's economy in 2010 (CDFA 2011, CalEDD 2011).

In addition to the direct contributions stemming from the sale of agricultural goods, crop production further stimulates economic activity within the state through the interdependency of farm and non-farm industries. Output from the farm sector provides food, intermediate goods, and stimulates growth in non-farm industries through the injection of new export earnings. In return, non-farm industries support agriculture through the sale of inputs (i.e. fertilizers, pesticides, and farm equipment) and establish markets for farm produce. These forward and backward linkages between suppliers explains how activity (or inactivity) in the farm sector can induce (or reduce) activity in seemingly unrelated industries.

The net value of current pest control in California is equal to the value of additional realized yields, or the value of forgone yield losses *(Price x Quantity),* minus the cost to apply control method. Their contribution to the overall state economy is equal to the value these protected yields add to the farm sector, plus the value of all induced activity in supporting industries. The direct contribution of these crop savings is equal to the additional jobs and revenue realized through the sale of these additional units. The secondary, or indirect plus induced contributions are equivalent to the additional jobs and income stemming from production and consumption linkages within the state's economy.

As crop production increases, demand for inputs rises, stimulating revenue and employment in industries producing input supplies. Those producers in turn require more of their own inputs further stimulating employment and revenue in sectors seemingly independent from California agriculture. The economic activity resulting from the derived demand for inputs and utilization of final demands is considered the indirect contribution. Increased production in these industries stimulates producer's demand and payments for labor, causing disposable household income for these laborers to rise. Increased disposable income would stimulate household consumption by enabling California households to purchase more goods and services for their own private use.

Previous studies and annual reports have discussed the direct contributions of California agriculture to the state's economy (CDFA, 2011, Carter and Goldman 1997, MFK, 2005, Sumner et al. 2004, Shwiff et al. 2006), the direct financial losses of vertebrate crop damage (Clark, 1976., NASS, 20002., OTA, 1979., Salmon, Crabb, and Marsh, 1986), and the economic impacts resulting from vertebrate pest damage (Hueth et al. 1997, Shwiff et al 2009), and the additional crop savings of innovative new control methods (Babcock and Lichtenberg, 1992, Bomford 1990, Prokopy et al. 2003, and Reichelderfer and Bender 1979). Although a few studies have tried to examine the unintended economic consequences of pest control removal (or economic contribution of pesticide use), these studies that have examined the reduction or elimination of specific chemical pesticides rather than animal specific control practices (Carter et al. 2004, Carter et al. 2005, Hamilton 2001, Knutson et al. 1990, Knutson et al. 1993, and Knutson et al. 1999). This study will add to the body of literature pertaining to vertebrate pest damage by examining the increased food production, lower production costs and market prices associated with current bird and rodent pest control practices for select California crops. In addition to estimating the market effects of California pest control use, this study will quantify the economic contributions of the yields protected through these practices.

1.6: Organization of Thesis

This thesis is organized into four chapters. The first chapter was designed to provide background information on California agriculture, agricultural pest damage, pesticide regulations in the United States, and the effects of reduced crop yield. Chapter 2 focuses on the methodology of data collection and analysis. This chapter will discuss the survey used to collect data and the economic framework employed to model avoided market changes and the contributions of crop savings. The third chapter will present and discuss the results from the survey, partial equilibrium model, and regional macroeconomic model. Chapter 4 will summarize key findings, discuss the limitations of this study, and propose future research.

CHAPTER 2: METHODOLOGY

2.1: Data Collection

This study utilized primary data collected from California producers through a simple survey. Although mail surveys have long been the preferred method for data collection, the substantial financial cost associated with the printing and mailing of materials were prohibitive. Employing a web-based survey enabled us to eliminate the substantial costs associated with obtaining and converting responses from a representative cross-section of California agricultural producers into an electronic format. This brief 15 minute questionnaire, hosted by SurveyMonkey, was designed to gather information on current control practices and estimates for crops and property damage with and without the use of control for producers' most profitable crops. A sample of the survey instrument can be found in Appendix A.

With the cooperation of California's Farm Bureau and a few crop specific producer groups, links to the SurveyMonkey questionnaire were included in their weekly Ag Alert newspaper with a brief write-up explaining the importance of collecting this information. This newspaper is currently sent to California Farm Bureau's 30,605 agricultural members. In addition to these reminder emails, the Farm Bureau also tweeted about it on their Twitter feed, posted the survey's link with a reminder on their Facebook page which has more than 2,000 followers, and sent two requests to county farm bureaus (many who went on to post it in their local newsletters).

The non-random sampling design used within this study is less than ideal, but given the time and budget allocated to this analysis it was the most practical way of obtaining responses from the subset of producers growing select California crops. It is important to note that results from this survey are may not be a representative sample of farmers in California and that the population included in the sample frame is not correctly identified. Since this study was intended to analyze the benefits of pesticide use in 22 California crops, the sample frame should have been limited to growers of these 22 crops, and included both member and non-member producers. Ideally a random sample would then be drawn from this sample frame.

2.2: Partial Equilibrium Model

To examine the effects of pest control removal on market outcomes for select California crops I employed partial equilibrium (PE) analysis on the data collected from the producer survey. By developing PE models for select California crops I was able to examine how a prohibition of bird and rodent pest control practices would affect prices, production, and social welfare in individual crop markets. This analysis is based on the assumptions that markets for California crops operate in equilibrium, demand is not dependent upon income so wealth effects are negligible, and changes in the market of any one crop will leave prices of all other goods approximately unchanged.

For this study, Aaron Anderson at NWRC adapted a PE model for agricultural commodities by relating prices and quantities of crops to acres planted and pest control costs. This model begins at the firm level with the basic profit maximization problem under the assumption that markets are competitive, individual firms are price takers who face horizontal demand curves, and that all firms produce a homogenous product. In this model firms are assumed to be identical, but production within California is differentiated from the rest of the country's so that production costs are allowed to vary between in-state and out-of-state producers. Allowing production costs to vary between producers in different regions enables us to examine how a prohibition on current pest control methods in California affects production in California and the rest of the country.

Since firms maximize profits by selecting quantities of inputs where the difference between total revenue and total costs is the greatest, producers are assumed to be using the optimal quantities of pest control and all other inputs. If pest control use in California was prohibited, these firms would be forced to choose suboptimal quantities of inputs which will affect prices, production, and profits within these markets. A mathematical representation of the PE model is as follows.

2.2.1 Profit Maximization

The profit maximization problem for each producing firm can be given by:

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

where:

$X \equiv acres\ planted$

$Z \equiv number\ of\ acres\ on\ which\ pest\ control\ applied$

$x \equiv per\ acre\ production\ cost\ excluding\ pest\ control\ costs$

$z \equiv per\ acre\ pest\ control\ costs.$

First order conditions for the maximization problem are:

$$\frac{\partial \pi}{\partial X} = P\frac{\partial q}{\partial X} - x = 0$$

$$\frac{\partial \pi}{\partial Z} = P\frac{\partial q}{\partial Z} - z = 0$$

Second order conditions:

$$\frac{\partial^2 \pi}{\partial X^2} \leq 0$$

$$\frac{\partial^2 \pi}{\partial Z^2} \leq 0$$

First order conditions imply that producers will apply pest control to an acre as long as the addition revenue earned by doing so is greater than the cost of application. Second order conditions for this profit maximization problem imply that profit function is concave and its extrema is a local maxima. Solving first order conditions gives the firm's input demand functions:

$$X_1^* = \mathrm{X}(P, x, z)$$

$$Z^* = Z(P, x, z),$$

Where X^*_1 and Z^* represent the optimal quantities of acres and pest control under current regulations.

Supply functions for individual producers can then be derived and are expressed as

$$q_1^* = q_1(X_1^*, Z^*)$$

$$or$$

$$q_1^* = q_1(P, x, z).$$

2.2.2 Initial Market Equilibrium

This model is built on the assumption that there are (m+n) identical firms participating in a perfectly competitive market for agricultural commodities, where n is the number of Californian firms and m is the number of U.S. producers operating outside of California. Taking the horizontal summation of these (m+n) individual supply curves gives the market supply curve.

When all producers are free from additional regulations restricting pest control, the market supply curve is given by:

$$Q_1 = a(m+n) + b(m+n)P$$

$$or$$

$$P_1 = \frac{{}^{Q}/_{b} - {}^{na}/_{b} - {}^{ma}/_{b}}{m+n}$$

Market supply is typically written as

$$Q_S = \alpha + \beta P$$
or
$$P_S = {}^{-\alpha}/_{\beta} + {}^{Q}/_{\beta},$$

where

$$\beta = \frac{E_S Q_1}{P_1}$$
$$\alpha = Q_1 - \beta P_1.$$

This implies that $\alpha = (m+n)$ and $\beta = b(m+n)$. Assuming demand is linear, it can be written as:

$$Q_D = \delta - \gamma P$$
or
$$P_D = {}^{-\delta}/_{\gamma} + {}^{Q}/_{\gamma},$$

Where:

$$\gamma = \frac{E_D Q_1}{P_1}$$
$$\delta = Q_1 - \gamma P_{1.}$$

The initial equilibrium quantity can be expressed as

$$Q_1 = \frac{{}^{-\alpha}/_{\beta} + {}^{\delta}/_{\gamma}}{{}^{1}/_{\gamma} - {}^{1}/_{\beta}}$$

$$P_1 = {}^{-\delta}/_{\gamma} + {}^{Q_1}/_{\gamma}.$$

In initial equilibrium consumer surplus can be measured by

$$CS_1 = \int_{P_1}^{-\delta/\gamma} (\delta - \gamma P)\,dP = \delta P - 0.5\gamma P^2 \Big|_{P_1}^{-\delta/\gamma}$$

and producer surplus for the whole market can be measured by

$$PS_1 = \int_0^{P_1} (\alpha - \beta P)\,dP = \alpha P - 0.5\beta P^2 \Big|_0^{P_1}$$

2.2.3 Pest Control Removal

Prohibiting pest control restricts *Z* to zero and affects the marginal cost functions of producers in two ways. First, the marginal cost function, which is the same as their supply function, shifts downward by an amount that reflects the eliminated pest control expenditures. Although producers lower input costs, the elimination of pest control measures causes pest damage to rise. Increased crop and property damage causes the marginal cost curve to shift left because yield per acre falls. These effects can be measured by estimating the average control cost per acre no longer purchased and the amount by which total industry output falls:

$$k = \frac{z}{yield\ per\ acre}$$

and

$$y = \left(q_1 \times \frac{\%\ yield\ loss}{100}\right) \times CA\ Market\ Share,$$

To simplify the model we assume the firm's marginal cost curve is linear and given by:

$$MC_1 = {}^{-a}/_{b} + {}^{q}/_{b}$$

or

$$q_1 = a + bP.$$

If pest control costs are eliminated, MC_1 will shift to MC' by the amount k. California producers will never operate at MC' because reduced spending on pest control will cause damage to rise by y, resulting in another simultaneous shift to MC_2.

$$MC' = {}^{-a}/_{b} - k + {}^{q}/_{b}$$

$$MC_2 = {}^{-a}/_{b} - k + {}^{1}/_{b}(q + y)$$

or

$$q_2 = a + bP + bk - y$$

2.2.4 New Equilibrium

Since firms are homogenous, in absence of region-specific regulations all firms will choose to make the same production decisions. In initial equilibrium firms are free to choose pest control practices and have a marginal cost curve of $q_1 = a + bP$. When pest control use is prohibited their marginal cost curve becomes $q_2 = a + bP + bk - y$. If firms in California become prohibited from using pest control, m firms will have marginal cost curves $q_1 = a + bP$

and *n* firms will have a marginal cost curve $q_2 = a + bP + bk - y$. Aggregating the individual supply curves for the $(m + n)$ firms would then give a market supply curve of:

$Q_S = n(a + bP + bk - y) + m(a + bP)$.

This supply function can then be rewritten in terms of the known parameters α and β, where as before

$$\alpha = a(m + n)$$
$$\beta = b(m + n).$$

Manipulating these relationships yields

$$\left(\frac{n}{n+m}\right)\alpha = an$$
$$\left(\frac{n}{n+m}\right)\beta = bn$$
$$\left(\frac{m}{n+m}\right)\alpha = am$$
$$\left(\frac{m}{n+m}\right)\beta = bn,$$

where $\left(\frac{n}{n+m}\right)$ and $\left(\frac{m}{n+m}\right)$ are equal to the fraction of domestic output produced by *n* Californian firms and *m* non-Californian firms, before Californian producers were prohibited from using pest control. To simplify notation let $f_n = \left(\frac{n}{n+m}\right)$ and $f_m = \left(\frac{m}{n+m}\right)$, so that the new market supply function can then be written as:

$$Q_S = f_n(\alpha + \beta P + \beta k) + f_m(\alpha + \beta P) - Y = \alpha + \beta P + f_n\beta k - Y$$

where

$$Y = ny = f_n Q_1 \times \frac{\%\ yield\ loss}{100}$$

Setting $Q_S = Q_D$ and solving for the new equilibrium yields

$$Q_2 = \delta + \frac{\gamma(\delta + Y - f_n\alpha - f_n\beta k - f_m\alpha)}{f_n\beta + f_m\beta - \gamma} = \delta + \frac{\gamma\delta + \gamma Y - \gamma\alpha - \gamma f_n\beta k}{\beta - \gamma}$$

and

$$P_2 = \frac{\delta + Y - f_n\alpha - f_n\beta k - f_m\alpha}{f_n\beta + f_m\beta - \gamma} = \frac{\delta + Y - \alpha - f_n\beta k}{\beta - \gamma}.$$

At the new equilibrium consumer surplus can be measured by

$$CS_2 = \int_{P_2}^{\delta/-\gamma} (\delta - \gamma P) dP = \delta P + 0.5\gamma P^2 \Big|_{P_2}^{\delta/-\gamma} \quad ,$$

with producer surplus for the whole market given by

$$PS_2 = \int_0^{P_2} (\alpha + \beta P + f_n\beta k - Y) dP = \alpha P + 0.5\beta P^2 + f_n\beta k P - YP \Big|_0^{P_2}$$

2.2.5 Disaggregation of Market Supply Functions

The previously derived market supply functions can be disaggregated so that the quantity supplied by all *n* and *m* firms can be given separately. The original market supply function can be written as:

$$Q_1 = a(m+n) + b(m+n)P = f_n\alpha + f_n\beta P + f_m\alpha + f_m\beta P.$$

Disaggregating this supply function yields:

$$Q_{n1} = f_n\alpha + f_n\beta P$$
$$Q_{m1} = f_m\alpha + f_m\beta P.$$

The market supply when pest control was removed from the n firms was derived as

$$Q_S = f_n(\alpha + \beta P + \beta k) + f_m(\alpha + \beta P) - Y.$$

Disaggregation of this supply function yields

$$Q_{n2} = f_n\alpha + f_n\beta P + f_n\beta P$$
$$Q_{m2} = f_m\alpha + f_m\beta P.$$

2.2.6 Changes in Surpluses

Since the prohibition of pest control use by Californian firms will affect each of the *n* and *m* firms differently, changes in producer surplus for in-state and out-of-state producers must be calculated separately. When pest control is allowed, the original producer surplus for the *n*-California firms is given by:

$$PS_{n1} = \int_{x}^{P_1} (f_n \alpha + f_n \beta P) dP = f_n \alpha P + 0.5 f_n \beta P^2 |_{x}^{P_1},$$

and for *m* firms outside of California is given by:

$$PS_{m1} = \int_{x}^{P_1} (f_m \alpha + f_m \beta P) dP = f_m \alpha P + 0.5 f_m \beta P^2 |_{x}^{P_1},$$

where $x = 0$ if $\alpha > 0$ and $x = {}^{-\alpha}/_{\beta}$ if $\alpha < 0$. This adjustment is to account for the possibility of a linear supply curve implying negative marginal cost of production.

When *n* firms in California are not allowed to use pest control, producer surplus is given by:

$$PS_{n2} = \int_{x}^{P_2} (f_n \alpha + f_n \beta P + f_n \beta k - Y) dP = f_n \alpha P + 0.5 f_n \beta P^2 + f_n \beta k P - YP |_{x}^{P_2},$$

where $x = 0$ if $f_n \alpha + f_n \beta k - Y > 0$ and $x = {}^{-\alpha}/_{\beta} - k + {}^{Y}/_{f_n \beta}$ if $f_n \alpha + f_n \beta k - Y < 0$.

At the new equilibrium, producer surplus for all other domestic firms given by

$$PS_{m2} = \int_{x}^{P_2} (f_m \alpha + f_m \beta P) dP = f_m \alpha P + 0.5 f_m \beta P^2 |_{x}^{P_2},$$

where: $x = 0$ if $\alpha > 0$ and $x = {}^{-\alpha}/_{\beta}$ if $\alpha < 0$.

The changes in producer and consumer surpluses resulting from a prohibition of bird or rodent pest control in California can then be calculated by taking the difference between surpluses in the new equilibrium and those from the initial equilibrium.

$$\Delta PS_n = PS^2{}_n - PS^1{}_n$$

$$\Delta PS_m = PS^2{}_m - PS^1{}_m$$

$$\Delta PS = \Delta PS_n + \Delta PS_m$$

$$\Delta CS = CS_2 - CS_1$$

2.3: Regional Macroeconomic Model

To quantify the economic activity stimulated by the yields protected through control practices, results from the partial equilibrium model were aggregated into five broad crop categories (fruit, tree nuts, grain, vegetable & melons, and all other crops) and used in a regional macroeconomic model. Using a regionalized macroeconomic model to simulate the loss of these yields enables the comparison of key economic indicators under conditions allowing and prohibiting the use of pest control. By comparing changes in productivity, income, and employment, we can measure the current contributions of crop savings realized through effective pest management.

2.3.1 Input-Output Modeling

Input-Output (IO's) models are the most widely used tool for modeling the linkages and leakages of an open economy. Pioneered by the Nobel Prize winning economist Wassily Liontief in the late 1930's, I-O models use transaction tables to illustrate how outputs from one industry may be sold to other industries as intermediate inputs or as a final good to consumers, and how payments in the form of wages and rents can then be used by households to purchase final demands (Richardson 1972). This allows you to track the monetary transactions that take place between an industry and other industries (processing), the payments to factors of production (value-added), and transactions between an industry and consumers of final goods (final demands).

The transactions in a basic, three-sector economy are shown in Table 1. Each row represents an industry as a producer of outputs, and each column represents an industry as a consumer of inputs. The top left-hand corner of the transaction table contains a three-by-three matrix, representing the sale of intermediate inputs between industries in a region. In this example, industry 1 sells goods and services to industries 2 and 3 (x_{11} to industry 1, x_{12} to industry 2, and x_{13} to industry 3); as well as purchases goods and services from industries 2 and 3 (x_{11} from industry 1, x_{21} from industry 2, and x_{31} from industry 3). Looking at the first row, we see that household (C_1) and other institutions (I_1) also purchased these goods and services from industry 1 as final demands. A portion of the revenue industry 1 collects through the sale of their goods and services is used for payments to labor (L_1), and to rents and imports in the form of value-added (V_1).

Table 1: Example of Transaction Table for Three Sector Economy

		Processing Sector			Final Demands		
Sales to		**X_1**	**X_2**	**X_3**	**Households**	**Other Institutions**	**Total Output**
Purchases From	**X_1**	x_{11}	x_{12}	x_{13}	C_1	I_1	X_1
	X_2	x_{21}	x_{22}	x_{23}	C_2	I_2	X_2
	X_3	x_{31}	x_{32}	x_{33}	C_3	I_3	X_3
Payments to Labor		L_1	L_2	L_3	L_c	L_I	L
Value Added		V_1	V_2	V_3	V_c	V_I	V
Total Outlays		X_1	X_1	X_1	C	I	X

Adding up row 1 shows that the gross output for industry 1 is equal to inter-industry sales (x_{11}, $x_{12,}$ and x_{13}) plus final demands ($C_1 + I_1$ or Y).

$$x_{11} + x_{12} + x_{13} + C_1 + I_1 = X_1$$

Or:

$$X_1 - x_{11} - x_{12} - x_{13} = Y$$

In order to calculate how a change in final demands (Y) affects industry 1's output (X_1), which is the underlying idea behind economic multipliers; technical coefficients must be calculated and applied. Technical coefficients illustrate the direct input requirements for each industry to produce $1 worth of outputs, and can be calculated by dividing the amount of inputs purchased from each industry by the industry's total outlay for inputs (Richardon 1979). For industry 1 these coefficients are often represented as $a_{1n} = x_{1n}/X_1$, where a_{1n} represents the amount of inputs n needed to produce one unit of 1. Substituting these coefficients into the final demand equation, final demand becomes a function of gross output and the required inputs.

$$X_1 - a_{11} \times x_{11} - a_{12} \times x_{12} - a_{13} \times x_{13} = Y$$

This equation can be put into matrix form for simplification, where X and Y are column vectors of gross output and final demand, and A is the matrix of technical coefficients:

$$X - A \times X = Y$$

$$\begin{bmatrix} X_1 \\ X_1 \\ X_1 \end{bmatrix} - \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \times \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

From here the direct effects of a change in final demands on gross output can be calculated. To measure the indirect effects of this change an identity matrix[1] *(I)* is introduced to create an inverse matrix $(I - A)^{-1}$, commonly known as Leontief inverse matrix. This inverse matrix transforms gross output into a function of exogenous final demand (Richardson 1972).

$$(I - A)\, X = Y$$

$$X = (I - A)^{-1} \times Y$$

The elements of this matrix represent the purchases of inputs from one industry to other industries in the region in order to produce an additional unit of output for the final demand.

[1] The inverse matrix $(I- A)^{-1}$ is an n×n matrix consisting of 1's in the diagonals and 0's everywhere else. Letting the inverse matrix $(I- A)^{-1}$ = B, the matrix AB will equal to matrix BA.

Since multiplying this matrix by the vector column of final demand (Y) will produce gross output (X), this matrix also represents the multiplier effects. Summing the individual industry columns of this matrix will then give you the industry multipliers.

To calculate the induced effects of this model, consumption by households and other institutions must be introduced into the technical coefficient matrix. By treating consumption of final demands as endogenous variables of the model the model can be closed (Richardson 1972).

IOM's are based on the key assumptions of linear input functions implying constant returns to scale and no substitution between inputs, no joint products (each commodity is sold by single industry, and all producers use the same method of production), no external economies and diseconomies (total output is the sum of individual outputs), prices are in equilibrium, and each commodity has a perfectly elastic supply (ruling out any capacity or capital constraints). Although these assumptions make I-O models an easy tool to use, they also create serious limitations including limiting their functionality to a short-run analysis and ignoring the effects of interregional competitiveness of inputs and the land-non-land substitution in urban analysis (Richardon 1979).

. Originally, I-O modeling was a very expensive and time intensive method because they required the collection of data from businesses, governments, and consumers through interviews and surveys (Loomis and Walsh 1997). But the invention of ready-made models has since made I-O models the most commonly used method to track the flow of income through a regional economy. Of these ready-made models, the three most commonly used are IMPLAN, RIMS II, and REMI (Rickman and Schwer 1995). A direct comparison of these three models is beyond the scope of this paper, but a table summarizing their characteristics can be found in Appendix B.

2.3.2 REMI

Since vertebrate pest damage is a dynamic problem, we chose to use a 70 sector REMI PI+ model v 1.2 to track changes over a ten year period. This structural economic forecasting model uses a non-survey based input-output table like other widely used ready-made models but links its I-O table to thousands of simultaneous equations in order to overcome the rigidness of static I-O models. By incorporating the strengths of input-output, computable general equilibrium, econometric and economic geography methodologies, REMI is able to overcome the limitations of any single model. This dynamic forecasting and policy tool has the ability to generate annual forecasts and simulations which detail behavioral responses to compensation, price, and other economic factors (REMI: Model Documentation – Version 9.5).

The structure of the model incorporates inter-industry transactions, endogenous final demand feedbacks, substitution among factors of production in response to changes in expected income, wage responses to changes in labor market conditions, and changes in the share of local and export markets in response to the change in regional profitability and production costs (Treyz, Rickman, and Shao, 1991). Exogenous variables are created using national, state, and county level data from the Bureau of Economic Analysis, Bureau of Labor Statistics, and the Bureau of the Census; and forecasts from the Research Seminar in Quantitative Economics at Michigan State University. The basis of this model is built upon the linkages between these exogenous variables and ones determined within the model, measuring how changes in outside factors create endogenous responses with the regional economy. Figure 4 illustrates how the overall structure of the model can be divided into five major interacting blocks: 1) output and demand, 2) labor and capital demands, 3) population and labor force, 4) wages, prices, and costs, and 5) market shares.

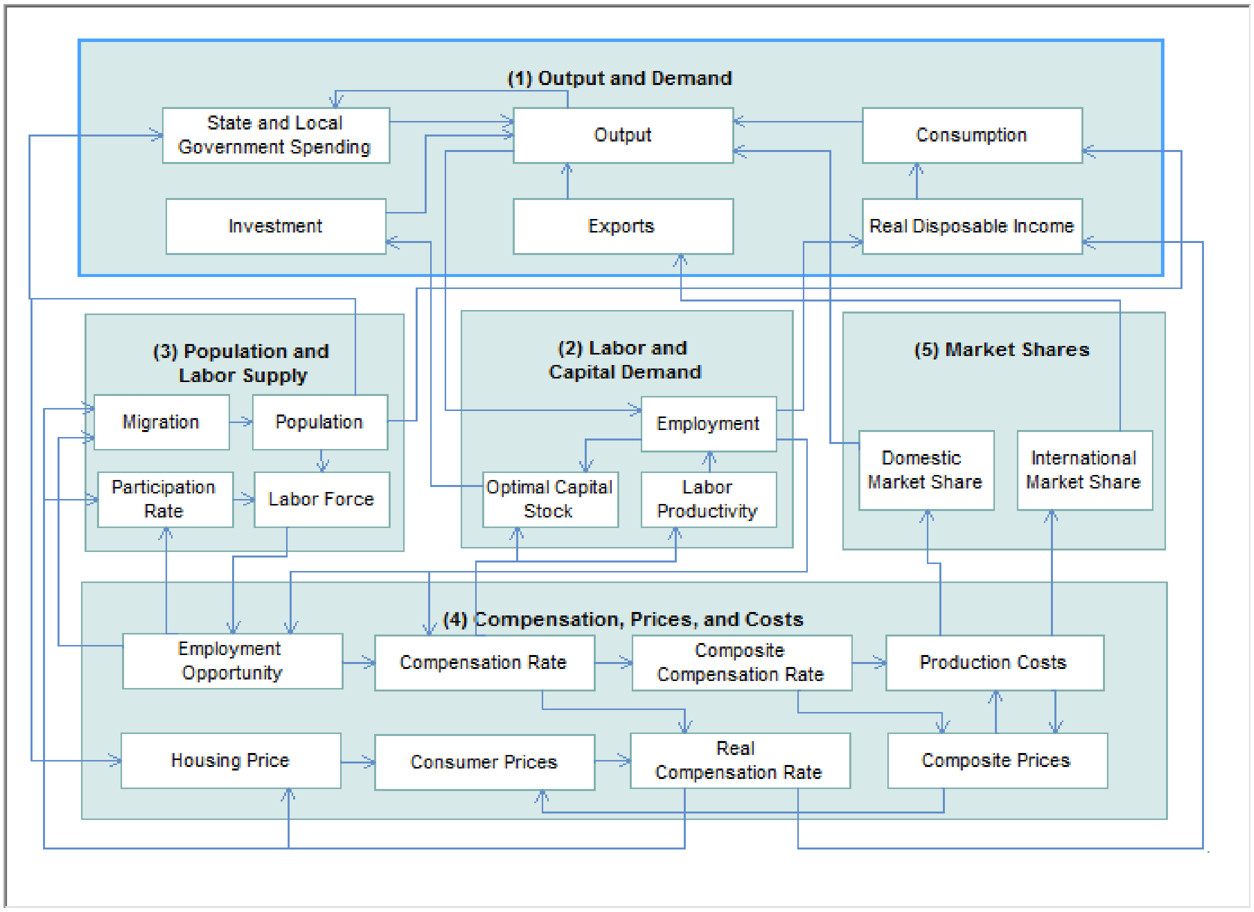

Figure 4: Linkages between Policy Variables in REMI Model

The output and demand block contains the input-output component of the model, and consists of output, demand, consumption, investment, government spending, exports, imports, and feedback from output change caused by changes in the production of intermediate goods. This block is driven by final demands, where the output of each industry in the region is determined by the demand of all regions in the nation, the region's share of the market, and the region's international exports. Consumption of these final goods depends on real disposable income per capita, relative prices, differential income elasticities, and population. Industry input productivity is determined by access to inputs because a larger choice set of inputs means it is more likely that the input with the specific characteristics required for the job will be found. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population. This block assumes intermediate inputs are used in fixed proportions, and factor input use is governed by the Cobb-Douglas functions in Block 2.

The second block, labor and capital demand, includes the determination of labor productivity, labor intensity and the optimal capital stocks. Industry-specific labor productivity is depends on the availability of workers with the differentiated skill set required by each industry, while the firm's access to this labor force is dependent upon the occupational labor supply and commuting costs. Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. The demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment; with optimal capital stock being contingent on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

The population and labor force block includes detailed demographic information about the region, including age, gender, and ethnicity (with birth and survival rates for each group). The region's labor supply is determined by the size and participation rate of each group; with these participation rates having the ability to respond to changes in employment relative to the potential labor force and to changes in the real after-tax wage rate. Migration is also accounted for in this block and includes retirement, military, international, and economic migration (determined by the relative real after-tax wage rate, relative employment opportunity, and consumer access to variety). The inclusion of migration can have powerful effects on block 1; increasing government spending through additional tax payments, inducing consumer spending through increased wage and nonwage income, and the increase in real disposable income can stimulate residential investment.

The fourth block includes wages, consumer prices, production costs, housing prices, composite wages, input costs, and the price deflator. Wages, prices, and costs are determined by the labor and housing markets; with wage rates determined by the interaction between demand for labor in block 2, and the supply of labor in block 3; and housing prices being respondent to changes in population density and real disposable income. The composite wage rate is determined by the labor access index in block 2, and the nominal wage rate. The composite cost of production depends on the region's productivity-adjusted wage rate, the costs of structures, equipment, and fuel, and the cost associated with importing intermediate inputs.

The cost of production for each industry is determined by the cost of labor, capital, fuel and intermediate inputs. Labor costs reflect the wage rate, and an adjusted productivity to account for access to specialized labor. Capital costs include costs of buildings and equipment, while fuel costs incorporate electricity, natural gas, and residual fuels.

The final block contains market shares equations to measure the proportion of local and export markets each industry is able to command. The proportion of the local market captured is known as the regional purchase coefficient, and the proportion of the export market is known as the interregional and international coefficient. The ability of a region to control market shares largely depends on production costs, estimated price elasticity of demand, and the distance between the home region and importing regions. The share of local and external markets then drives the exports from and imports to the home economy.

The interdependence between blocks leads to endogenous responses, which REMI allows users to control for. If the econometric responses are completely suppressed, the model collapses into an input-output model. Suppressing labor intensities, labor supply, wage rates, industry RPC's, and endogenous final demands responses will produce Type I input-output multipliers. Type II multipliers can be obtained from the REMI model by allowing consumption to be endogenously determined. And allowing the full use of econometric responses will produce Type III multipliers, which were used in this study. This Type III multiplier differs from standard Type III input-output multipliers because of the endogeneity of export and propensity to import responses in the REMI model (Rickman and Schwer 1995).

Although multipliers can be retrieved from REMI output, the endogeneity of the model takes away much of the meaning behind them (McMillen, 2006). Static models estimate multipliers by modeling changes in economic activity stemming from changes in final demands to a snapshot of current economic conditions. The dynamic nature of REMI enables it to create a control (baseline) forecast which projects economic conditions within a region based on trends in historical data. Economic impacts are then examined by comparing the control forecast to simulations which can model changes in more than 100 different policy variables, including industry specific income, value added, and employment.

REMI has continuously been improved upon since its development in 1980, with numerous publications outlining the model's specifications (Treyz, Rickman, and Shao, 1991, Greenwood et al. 1991, Treyz et al. 1993, Rickman, 1997).Even though REMI is one of the more expensive regional economic models, its adoption by researchers employed by consulting firms, government agencies, utilities, non-profits, and academic institutions continues to grow. REMI has been used to measure cause and effect relationships for a wide range of research topics, including: environmental issues (Rose et al. 2012, , Warren et al., 2010, LaFleur and Yeates, 2005), economic development (Connor et al. 2009, Institute of Labor & Industrial Relation.

2004), energy (Greenberg et al. 2002, Treyz, Nystrom, and Cui, 2011), taxation and public policy (England, 2007, Merkowit, 2008, Hogan, 2004, Rose et al. 2011), transportation (Wilber Smith Associates. 1998, McGrath, 1996) population growth and migration (Swanson et al. 2009, Felsenstein, 2002, Fulton and Grimes,2008), human health care (Livingood et al., 2007, Croucher and James, 2010, Rephann, 2010), and recreation and tourism (Treyz and Leung, 2009, Robey and Kleinhenz, 2000). Although REMI has been used to model agricultural impacts of draughts (Warren et al., 2010) and increased water salinity (UCDavis, 2009), this will be the first time it has been applied to agricultural pest issues.

CHAPTER 3 –RESULTS & DISCUSSION

Chapter 3 will be divided into four sections and will focus on presenting the study's findings. Section 1 will summarize results from the California producer survey and provide valuable information on the cost of current pest control practices, and damage estimates with and without its use. Section 2 will discuss the market changes estimated using a partial equilibrium model used for select California crops. Section 3 will present the results of the regional macroeconomic forecasting model to examine the contributions these crop savings provide to California's broader economy. The final section will provide a brief discussion on the implications of these findings and suggest areas of further research

3.1: Survey Results

Over a 3 month period we received 475 responses from California producers regarding their primary crop, with 153 of these responses including information on their second most important crop, resulting in 628 observations. Responses that used vague crop categories such as stone fruit, row crop, or vegetables, and those from livestock and livestock product producers were excluded from the sample. In total we received 581 survey responses for 53 different crops. Since producer records are not frequently updated and survey links were sent out via social networking sites where only a percentage of followers are actual growers, it was impossible to determine how many links were received by California producers. Not having this information prevented a survey response rate from being estimated.

Summary statistics and outlier analysis of survey responses can be found in Appendix C. Although responses for 53 crops were recieved, this thesis modeled 22 (alfalfa, almonds, avocados, carrots, cherries, citrus (lemons, oranges), grapes (raisin, table, and wine), lettuce, melons (cantaloupe, honeydew, watermelon), peaches, pistachios, rice, spinach, strawberries, tomatoes (fresh and processing), and walnuts) in order to build upon the 2008 Shwiff et al. study which analyzed the economic impacts of bird and rodent damage to these crops in 10 California counties. It is very important to note that the sample size for many of these crops was limited to a few responses. Since it is uncertain whether these small samples are representative of the larger population of California producers, the results and discussion section will focus primarily on the three crops which had more than 50 responses- Wine Grapes (84), Avocados (83), and Citrus (54) under the assumption that these are representative samples.

Of the 581 responses, 80 percent of producers reported suffering crop damage from rodents and 48 percent reported bird damage. More than 75 percent of these producers reported that ground squirrels and gophers were the primary cause of rodent damage, while crows and ravens were reported as the most common cause of bird damage. On average, California producers reported spending $11.61 an acre on rodent control and $8.21 an acre on bird control. The most widely used control methods included toxicants (67%) and trapping (52%) for rodents, and sound (22%) and visual scare devices (28%) for birds. Figure 5 shows the percentage of California producers reporting the use of each control method.

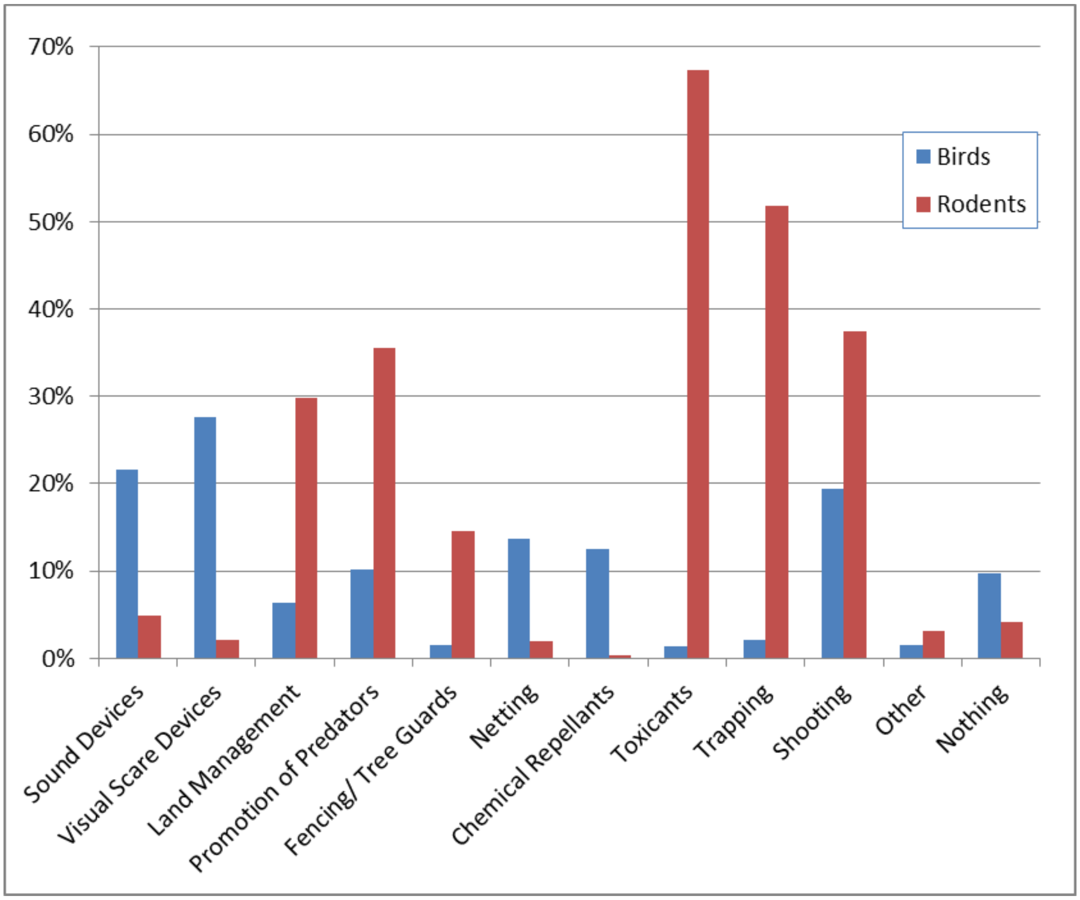

Figure 5: Reported Pest Control Use in California

Table 2 compares responses collected from the 22 select crops as compared to overall California production reported in the most recent National Agricultural Statistical Services Census of Agricultural. When samples for individual crops are compared to 2007 crop statistics it becomes evident that the relatively small samples may not be representative of the larger population of producers within the state. Comparing average reported acres to the median acres in production provides evidence to suggest that using Farm Bureau members as the sample frame may have led to the underrepresentation of small scale operations in the sample frame. Since a survey response rate could not be estimated it is unclear whether smaller operations were in fact underrepresented in the sample frame or if larger operations were more likely to respond to the survey because pest damage was a more prevalent issue for large scale growers.

Table 2: Sample Compared to State Statistics

Crop	Number of Responses	Producers in California[a]	Average Acres Reported	Median Operation Size (Acres)[a]
Alfalfa*	19	4,373	356	50-99.9
Almonds	49	6,474	373	25-49.9
Avocados	83	6,230	63	1-4.99
Carrots	1	326	225	1-4.9
Cherries	9	1,115	85	5-14.9
Citrus	54	7,027	204	5-14.9
Grapes- Raisin	11	Not Available	328	Not Available
Grapes-Table	14	Not Available	267	Not Available
Grapes- Wine	84	Not Available	241	Not Available
Lettuce	11	753	2,006	1-4.9
Melons	4	990	1,376	0.1-0.9
Peaches	4	1,834	119	5-14.9
Pistachios	7	936	1,005	25-49.9
Rice	10	1,304	739	250-499
Spinach	1	174	250	Not Available
Strawberries	3	719	303	5-14.9
Tomatoes-Fresh	4	1,344	7	0.1-0.9
Tomatoes-Proc	8	490	363	200-499
Walnuts	31	5,712	218	5-14.9

[a]*Overall California production numbers taken from NASS 2007 Census of Agriculture*
**CA Alfalfa figures were estimated as a percentage (59%) of total Hay and Haylage operations in 2007. Percentage was equivalent to alfalfa's percentage of total acres harvested*

3.1.1 Rodent Damage

California producers reported significant rodent damage and survey results indicated that producers relied on a variety of rodent control measures to mitigate rodent damage. Producers of the 19 crops selected for further analysis reported that toxicants were the most widely used control method, closely followed by trapping. Fifty percent or more of producers for these select crops reported using rodenticides (toxicants), with the exception of rice and spinach producers. Table 3 shows the percentage of producers reporting the use of each control method.

Table 3: Rodent Control Practices for Select California Crops

Crop	Sound Devices	Visual Scare Devices	Land Mgmt	Promotion of Predators	Fencing/ Tree Guards	Netting	Chemical Repellant	Toxicants	Trapping	Shooting	Nothing	Other
Alfalfa	0%	0%	63%	42%	0%	0%	5%	74%	53%	37%	0%	10%
Almonds	0%	2%	37%	33%	16%	2%	14%	88%	53%	63%	0%	0%
Avocados	7%	2%	12%	29%	12%	4%	14%	70%	66%	34%	5%	0%
Carrots	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Cherries	0%	0%	11%	11%	0%	0%	0%	67%	33%	0%	0%	0%
Citrus	7%	2%	26%	39%	13%	2%	11%	67%	56%	30%	2%	4%
Grapes- Raisin	9%	0%	27%	36%	18%	0%	18%	64%	55%	64%	9%	0%
Grapes-Table	7%	0%	26%	43%	14%	7%	14%	86%	50%	29%	7%	14%
Grapes- Wine	0%	1%	38%	56%	15%	1%	13%	60%	55%	27%	5%	1%
Lettuce	0%	0%	64%	18%	27%	0%	9%	64%	45%	36%	0%	0%
Melons	50%	0%	0%	25%	50%	0%	25%	50%	0%	0%	0%	0%
Peaches	25%	0%	0%	0%	0%	0%	50%	75%	25%	0%	0%	0%
Pistachios	0%	0%	29%	57%	29%	0%	14%	71%	29%	43%	0%	14%
Rice	10%	10%	40%	0%	10%	0%	10%	30%	20%	30%	0%	0%
Spinach	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Strawberries	0%	0%	33%	0%	67%	0%	33%	100%	100%	0%	0%	33%
Tomatoes- Fresh	50%	0%	0%	25%	0%	25%	0%	50%	75%	25%	25%	0%
Tomatoes- Proc	25%	0%	25%	50%	0%	0%	13%	88%	25%	25%	0%	0%
Walnuts	10%	7%	20%	23%	13%	3%	10%	73%	3%	6%	10%	7%

On average, producers of these select crops reported spending between \$0.20 (spinach) and \$49.01 (strawberries) per acre on various rodent control measures. Nearly all producers indicated current control practices were successful at reducing rodent damage, but not completely effective at eliminating crop loss and property damage. Results for individual crops are provided in Tables 3 and 4.

Table 4: Per Acre Rodent Control Costs and Property Damage

Crop	Per Acre Control	Per Acre Property Damage With Control	Per Acre Property Damage Without Control
Alfalfa	\$ 19.39	\$ 19.24	\$ 105.58
Almonds	\$ 9.78	\$ 11.78	\$ 61.59
Avocados	\$ 25.85	\$ 20.30	\$ 70.05
Carrots	\$ 8.89	\$ 22.22	\$ 100.00
Cherries	\$ 34.51	\$ 12.43	\$ 77.19
Citrus	\$ 16.75	\$ 74.91	\$ 237.22
Grapes- Raisin	\$ 5.14	\$ 18.16	\$ 287.96
Grapes-Table	\$ 5.30	\$ 9.50	\$ 42.40
Grapes- Wine	\$ 24.73	\$ 11.12	\$ 709.95
Lettuce	\$ 1.04	\$ 2.63	\$ 5.53
Melons	\$ 5.09	\$ 12.72	\$ 29.08
Peaches	\$ 3.21	\$ 4.40	\$ 18.43
Pistachios	\$ 7.78	\$ 4.48	\$ 21.56
Rice	\$ 0.63	\$ 1.22	\$ 2.31
Spinach	\$ 0.20	\$ 0.80	\$ 1.20
Strawberries	\$ 49.01	\$ 70.17	\$ 187.12
Tomatoes-Fresh	\$ 46.04	\$ 183.02	\$ 1,008.96
Tomatoes-Proc	\$ 10.16	\$ 16.35	\$ 105.36
Walnuts	\$ 12.15	\$ 21.90	\$ 88.12

In addition to the considerable out-of-pocket costs associated with repairing farm structures and equipment, California producers reported suffering crop damage from rodent activities. Producers for all 19 crops reported yield losses with current control practices, and all producers, with the exception of spinach, reported substantial increases in yield losses without control. The difference between current yield loss with control and yield loss under a prohibition is considered the yield savings, or the amount of each crop protected through current rodent management. In the absence of control producers reported that Citrus harvests would fall by 18.4 percent per acre, with Wine Grape and Avocado harvests falling by 17.6 and 9.6 percent respectively.

Table 5: Yield Losses with and without Rodent Control

Crop	Current Yield Loss	Yield Loss Without Control	Yield Savings
Alfalfa	7.75%	39.46%	34.52%
Almonds	2.73%	21.07%	18.86%
Avocados	4.90%	15.90%	9.63%
Carrots	2.00%	20.00%	18.36%
Cherries	4.33%	16.83%	13.06%
Citrus	3.24%	21.08%	18.44%
Grapes- Raisin	2.67%	14.67%	12.33%
Grapes-Table	2.88%	13.76%	11.20%
Grapes- Wine	4.23%	21.07%	17.58%
Lettuce	1.72%	9.36%	7.77%
Melons	1.45%	11.67%	10.35%
Peaches	2.92%	23.33%	21.03%
Pistachios	2.89%	12.21%	9.60%
Rice	1.69%	4.86%	5.83%
Spinach	2.00%	2.00%	0.00%
Strawberries	12.71%	27.08%	16.46%
Tomatoes-Fresh	4.50%	16.25%	12.30%
Tomatoes-Proc	9.19%	46.88%	41.50%
Walnuts	5.89%	25.19%	20.51%

3.1.2 Bird Damage

Results highlighted the differences in bird and rodent agricultural damage, control practices, and the susceptibility of crops to different kinds of damage. Bird damage reported by producers was attributed to a wider variety of species, with the majority of bird damage reported by producers of California select crops attributed to crows and ravens. Since numerous federals laws protecting migratory and threatened birds significantly limit the use of lethal avian control measures, California producers indicated they relied heavily upon sound and visual scare devices to deter bird activity and spent up to $121.70 per acre on control. See Table 6 for a detailed breakdown of reported control practices by crop.

Survey responses indicated that producers growing fruits and sweet vegetables were more vulnerable to bird damage. Tables 6 and 7 summarize producer control and damage estimates for the selected 19 crops with and without avian pest control. Since agricultural losses from birds stems more from the consumption of crops than from destructive burrowing and gnawing activities like with rodents, reports of property damage caused by birds was considerably less for the majority of these crops. Avocado and Citrus producers both reported spending less than $1 per acre on bird control, and only incurred 20 cents and $1 per acre of property damage, respectively. Vineyards reported to be more prone to bird damage in terms of both property and crop damage, with substantial increases in both under a prohibition of current control practices. In the absence of these controls wine grape growers reported that per acre property damage would increase by $115 and that harvested yields would fall by 33 percent an acre.

Table 6: Bird Control Practices in Select California Crops

Crop	Sound Devices	Visual Scare Devices	Land Mgmt	Promotion of Predators	Fencing/ Tree Guards	Netting	Chemical Repellant	Toxicants	Trapping	Shooting	Nothing	Other
Alfalfa	5%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	0%
Almonds	45%	29%	4%	8%	0%	4%	0%	0%	0%	41%	0%	0%
Avocados	2%	6%	0%	2%	1%	8%	0%	0%	0%	5%	18%	0%
Carrots	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Cherries	56%	22%	0%	22%	11%	0%	11%	11%	11%	44%	11%	0%
Citrus	4%	11%	0%	4%	2%	4%	2%	2%	0%	2%	11%	0%
Grapes- Raisin	45%	45%	0%	36%	0%	18%	0%	0%	0%	27%	0%	0%
Grapes-Table	57%	50%	7%	29%	0%	14%	7%	0%	29%	57%	0%	0%
Grapes- Wine	36%	49%	11%	24%	1%	46%	1%	0%	1%	21%	8%	4%
Lettuce	36%	82%	36%	36%	9%	0%	0%	9%	9%	45%	0%	18%
Melons	75%	75%	0%	0%	0%	25%	25%	0%	0%	0%	0%	25%
Peaches	50%	25%	0%	50%	0%	25%	0%	0%	0%	50%	0%	0%
Pistachios	86%	71%	0%	14%	0%	14%	0%	14%	14%	71%	0%	0%
Rice	70%	40%	30%	0%	0%	0%	0%	0%	0%	40%	10%	0%
Spinach	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Strawberries	67%	100%	33%	33%	0%	67%	0%	0%	33%	0%	0%	0%
Tomatoes- Fresh	25%	50%	0%	50%	0%	0%	0%	0%	0%	25%	25%	0%
Tomatoes-Proc	25%	50%	0%	13%	0%	0%	0%	0%	0%	13%	0%	0%
Walnuts	17%	27%	10%	7%	0%	3%	0%	0%	0%	33%	13%	0%

Table 7: Per Acre Bird Control Costs and Property Damage

Crop	Per Acre Control	Per Acre Property Damage	Per Acre Property Damage Without Control
Alfalfa	$ 0.45	$ 1.36	$ 4.05
Almonds	$ 2.30	$ 5.61	$ 12.28
Avocados	$ 0.42	$ 1.00	$ 7.50
Carrots	$ -	$ 2.22	$ 2.22
Cherries	$ 3.58	$ 2.80	$ 99.77
Citrus	$ 0.38	$ 0.20	$ 0.22
Grapes- Raisin	$ 4.74	$ 22.79	$ 323.94
Grapes-Table	$ 14.31	$ 225.43	$ 1,409.61
Grapes- Wine	$ 41.01	$ 4.60	$ 119.90
Lettuce	$ 1.04	$ 3.64	$ 13.99
Melons	$ 1.63	$ 6.44	---
Peaches	$ 1.26	$ 2.51	$ 89.39
Pistachios	$ 8.84	$ 2.89	$ 7.19
Rice	$ 1.86	$ 2.11	$ 17.81
Spinach	$ 2.80	$ 4.00	$ 4.00
Strawberries	$ 121.70	$ 148.68	$ 242.29
Tomatoes-Fresh	$ 15.39	$ 38.48	$ 406.65
Tomatoes-Proc	$ 1.61	$ 4.58	$ 79.92
Walnuts	$ 4.12	$ 10.43	$ 20.61

Table 8: Yield Losses with and without Bird Control

Crop	Current Yield Loss	Yield Loss Without Control	Yield Savings
Alfalfa	5.63%	9.08%	3.99%
Almonds	2.14%	8.37%	5.75%
Avocados	1.00%	2.70%	1.74%
Carrots	1.00%	2.50%	1.51%
Cherries	6.56%	22.22%	16.49%
Citrus	0.97%	3.02%	2.07%
Grapes- Raisin	4.54%	19.44%	15.61%
Grapes-Table	7.18%	22.25%	16.23%
Grapes- Wine	6.30%	36.99%	32.75%
Lettuce	2.05%	15.47%	13.70%
Melons	1.17%	6.50%	6.49%
Peaches	12.75%	42.50%	34.09%
Pistachios	4.07%	16.48%	12.88%
Rice	2.01%	12.21%	10.41%
Spinach	10.00%	50.00%	44.44%
Strawberries	5.83%	18.33%	13.27%
Tomatoes-Fresh	3.35%	10.20%	7.09%
Tomatoes-Proc	2.63%	16.88%	14.63%
Walnuts	4.79%	11.42%	6.96%

3.2 Partial Equilibrium Model

Survey responses indicated that current pest control practices in California were highly effective in reducing agricultural damage, and provided estimates of control costs and yield losses for individual California crops. These estimates provided the information needed to calculate the percentage of yield per acre protected by current control practices, which were then entered into partial equilibrium models for the select California crops. Since prices at the farm level are given by individual crop, citrus was further broken into oranges and lemons, and melons were divided into cantaloupe, honeydew, and watermelon. Crop specific short-run and long-run supply and demand elasticities coupled with cost and yield estimates enabled us to model how these additional yields affected market outcomes over different time horizons. In the short-run factors of production are relatively fixed and few, if any, substitutes exist for many of the crops grown in California. These limited options imply that both producers and consumers are somewhat unresponsive to initial price changes, or that supply and demand is relatively inelastic. Changes in technology and tastes and preferences occurring over time have been shown to increase elasticity in markets over the long run. Since removal of pest control will affect outcomes in agricultural markets indefinitely, this analysis modeled both its short term and long term impacts.

Changes in market outcomes for agricultural goods includes changes in crop production and market supply, farm revenue and prices, and changes in U.S. producer and consumer surpluses. Examining the use of current control practices in the production of select California crops in terms of the increased production and farm revenue, and reduced consumer expenditures, realized through the additional yields these control practices protect will provide a better understanding of the social benefits and economic contributions of their use.

The partial equilibrium model estimated how yields protected through effective pest management affected production within and outside of California, and quantified the contributions these protected yields provide towards the domestic supply of these crops. Tables 9 and 10 summarize the contributions of bird and rodent pest control in terms of protected yields, and units supplied by California and out of state producers for select California crops.

Table 9: Short-Run Production Changes without Rodent Control

Crop	% Yield Loss Without Control	CA Production (Units)	Outside-CA Production (Units)	Net Change in US Supply (Units)
Fruit				
Avocado (tons)	9.63	-13,859	752	-13,107
Cherries (tons)	13.06	-7,301	5,456	-1,845
Grapes-Raisin (tons)	12.33	-98,187	-	-98,187
Grapes-Table (tons)	11.20	-49,188	3,830	-45,359
Grapes-Wine (tons)	17.58	-183,623	87,878	-95,745
Lemon (box=76lbs)	18.44	-2,218,819	115,996	-2,102,823
Oranges (box=75lbs)	18.44	-9,056,371	2,609,060	-6,447,311
Peach (tons)	21.03	-104,387	21,214	-83,173
Strawberries (cwt)	16.47	-2,527,444	1,497,417	-1,030,027
Grain				
Rice (cwt)	5.83	-1,983,907	1,738,631	-245,276
Hay				
Alfalfa (tons)	34.52	-2,385,495	957,729	-1,427,766
Tree Nuts				
Almonds (lbs)	18.86	-218,895,066	-	-218,895,066
Pistachios (lbs)	9.61	-16,837,800	-	-16,837,800
Walnuts (tons in shell)	20.51	-71,401	-	-71,401
Vegetable & Melon				
Cantaloupe (cwt)	10.36	-514,271	474,343	-39,928
Carrot (cwt)	18.37	-2,940,726	157,866	-2,782,860
Honeydew (cwt)	10.36	-94,109	84,530	-9,579
Lettuce (cwt)	7.77	-1,681,601	552,553	-1,129,048
Spinach (cwt)	-	51	-29	22
Tomato- Fresh (cwt)	12.30	-1,277,792	231,508	-1,046,283
Tomato-Proc (tons)	41.50	-3,346,276	62,098	-3,284,178
Watermelon (cwt)	10.36	-544,696.15	522,881	-21,815

Table 10: Short-Run Production Changes without Bird Control

Crop	% Yield Loss Without Control	CA Production (Units)	Outside-CA Production (Units)	Net Change in US Supply (Units)
Fruit				
Avocado (tons)	1.74	-2,459	147	-2,312
Cherries (tons)	16.50	-9,487	7,089	-2,398
Grapes-Raisin (tons)	15.61	-73,673	-	-73,673
Grapes-Table (tons)	16.23	-104,707	8,152	-96,555
Grapes-Wine (tons)	32.75	-343,134	164,217	-178,918
Lemon (box=76lbs)	2.07	-249,718	13,055	-236,663
Oranges (box=75lbs)	2.07	-1,027,666	296,061	-731,604
Peach (tons)	34.10	-169,531	34,453	-135,078
Strawberries (cwt)	13.27	-2,004,171	1,187,397	-816,773
Grain				
Rice (cwt)	10.41	-3,528,325	3,092,109	-436,216
Hay				
Alfalfa (tons)	4.00	-277,489	111,406	-166,083
Tree Nuts				
Almonds (lbs)	5.75	-66,752,106	-	-66,752,106
Pistachios (lbs)	12.88	-22,623,970	-	-22,623,970
Walnuts (tons in shell)	6.96	-24,241	-	-24,241
Vegetable & Melon				
Cantaloupe (cwt)	6.49	-324,144	298,978	-25,166
Carrot (cwt)	1.52	-243,428	13,068	-230,360
Honeydew (cwt)	6.49	-59,421	53,373	-6,048
Lettuce (cwt)	13.70	-2,965,980	974,584	-1,991,396
Spinach (cwt)	44.44	-793,207	314,846	-478,361
Tomato- Fresh (cwt)	7.09	-739,182	133,924	-605,258
Tomato-Proc (tons)	14.63	-1,182,001	21,935	-1,160,066
Watermelon (cwt)	6.49	-342,499.07	328,782	-13,717

Current rodent control practices enable California growers to supply more than 90 percent of U.S. avocados, lemons, and wine grapes, with nearly 14,000 tons of avocados, 2 million boxes of lemons, and more than 180,000 tons of wine grapes. Without California pest control out-of-state production would increase slightly to compensate for a small portion of these losses, but overall market supply for these crops would fall. In the absence of bird controls, the annual U.S. supply of avocados was estimated to fall by roughly 2,400 tons, lemons by nearly 250,000 boxes, and wine grapes by more than 343,000 tons. Without California rodent controls, annual domestic supply of avocados would decline by approximately 13,000 tons, lemons by more than 3 million boxes, and U.S. wine grapes by nearly 96,000 tons. The impacts of these yield losses were shown to be even more significant for nut crops and raisin grapes since production could not be shifted to out-of-state producers.

Results from the short run PE models showed that the loss of these additional yields would significantly affect wholesale prices for these crops, and farm revenue nationwide. Short run price increases ranged from 0 (spinach) to 60.30 percent (walnuts) with the elimination of rodent control, and from 0.39 (oranges) to 51.30 percent (spinach) in the absence of bird controls. Although yield savings were shown to have a negative effect on prices, higher prices were not always shown to translate into greater expenditures and farm revenue. Expenditures on wine grapes was estimated to rise by more than $300 million when yields were not protected from rodents, increasing producers' revenue in California by $166 million and revenue outside California by $134 million annually. Prices were shown to have increased for lemons as well, but revenue from California producers was estimated to fall by $10.9 million, with total domestic lemon wholesale sales falling by $870,813 annually. Tables 11 and 12 summarize findings for select California crops.

Table 11: Short-Run Effects of Rodent Control Removal on Farm Revenues

Crop	Change in Price	% Change in Price	Consumer Expenditure	CA Total Revenue	Outside-CA Total Revenue
Fruit					
Avocado (tons)	$ 173.68	9.87	$ 12,473,783.27	$ 7,237,292.51	$ 5,236,490.76
Cherries (tons)	$ 88.49	3.44	$ 20,215,921.11	$ -13,031,021.60	$ 33,246,942.71
Grapes-Raisin (tons)	$ 23.83	8.22	$ 7,877,032.01	$ 7,877,032.01	$ -
Grapes-Table (tons)	$ 50.62	6.90	$ 9,941,518.61	$ 319,597,884.02	$ 6,745,539.78
Grapes-Wine (tons)	$ 92.98	15.11	$ 300,412,356.80	$ 166,063,652.45	$ 134,348,704.35
Lemon (box=76lbs)	$ 3.27	11.74	$ -870,813.49	$ -10,952,480.13	$ 10,081,666.64
Oranges (box=75lbs)	$ 0.38	3.43	$ 4,845,164.48	$ -82,385,665.83	$ 87,230,830.30
Peach (tons)	$ 42.73	11.36	$ 11,580,952.27	$ -7,948,484.70	$ 19,529,436.97
Strawberries (cwt)	$ 3.19	4.74	$ 97,641,672.21	$ -108,537,983.75	$ 206,179,655.96
Grain					
Rice (cwt)	$ 0.31	1.54	$ 56,001,584.92	$ -27,103,434.64	$ 83,105,019.56
Hay					
Alfalfa (tons)	$ 23.88	14.04	$ 115,226,920.90	$ -287,221,355.02	$ 1,438,556,138.93
Tree Nuts					
Almonds (lbs)	$ 0.42	22.97	$ 80,153,695.16	$ 80,153,695.16	$ -
Pistachios (lbs)	$ 0.10	5.42	$ -1,711,895.73	$ -1,711,895.73	$ -
Walnuts (tons in shell)	$ 1,099.52	60.30	$ 198,132,674.95	$ 198,132,674.95	$ -
Vegetable & Melon					
Cantaloupe (cwt)	$ 0.90	5.78	$ 17,025,229.35	$ 1,897,842.33	$ 15,127,387.02
Carrot (cwt)	$ 1.83	7.59	$ -27,435,675.70	$ -39,132,600.65	$ 11,696,924.95
Honeydew (cwt)	$ 1.12	6.81	$ 4,341,764.34	$ 1,460,837.50	$ 2,880,926.84
Lettuce (cwt)	$ 2.45	11.45	$ 114,491,845.87	$ 66,481,878.05	$ 48,009,967.82
Spinach (cwt)	$ (0.00)	0.00	$ -3,631.00	$ -1,659.20	$ -1,971.80
Tomato- Fresh (cwt)	$ 1.50	3.86	$ 8,292,639.73	$ -34,436,666.25	$ 42,729,305.98
Tomato-Proc (tons)	$ 21.41	28.84	$ -60,136,920.52	$ -77,310,257.99	$ 17,173,337.47
Watermelon (cwt)	$ 0.22	1.60	$ 8,114,607.65	$ -6,115,389.39	$ 14,229,997.04

Table 12: Short-Run Effects of Bird Control Removal on Farm Revenues

Crop	Change in Price	% Change in Price	Consumer Expenditure	CA Total Revenue	Outside-CA Total Revenue
Fruit					
Avocado (tons)	$ 34.03	2.00	$ 3,263,697.63	$ 2,258,196.20	$ 1,005,501.44
Cherries (tons)	$ 114.98	4.47	$ 26,203,809.51	$ -17,183,006.94	$ 43,386,816.45
Grapes-Raisin (tons)	$ 18.44	6.37	$ 6,493,365.35	$ 6,493,365.35	$ -
Grapes-Table (tons)	$ 107.76	14.70	$ 15,645,836.59	$ 820,789.09	$ 14,825,047.51
Grapes-Wine (tons)	$ 173.75	28.24	$ 546,924,981.44	$ 282,605,227.24	$ 264,319,754.20
Lemon (box=76lbs)	$ 0.37	1.32	$ 589,380.42	$ -507,345.60	$ 1,096,726.02
Oranges (box=75lbs)	$ 0.04	0.39	$ 795,155.64	$ -9,004,016.86	$ 9,799,172.51
Peach (tons)	$ 69.40	18.45	$ 15,205,928.59	$ -17,429,833.06	$ 32,635,761.64
Strawberries (cwt)	$ 2.53	3.76	$ 77,965,532.76	$ -84,743,415.62	$ 162,708,948.39
Grain					
Rice (cwt)	$ 0.55	2.74	$ 99,493,239.34	$ -49,044,445.64	$ 148,537,684.98
Hay					
Alfalfa (tons)	$ 2.78	1.63	$ 137,431,856.47	$ -27,555,132.16	$ 164,986,988.63
Tree Nuts					
Almonds (lbs)	$ 0.13	7.00	$ 44,056,375.11	$ 44,056,375.11	$ -
Pistachios (lbs)	$ 0.14	7.28	$ -3,090,610.24	$ -3,090,610.24	$ -
Walnuts (tons in shell)	$ 373.29	20.47	$ 84,870,208.81	$ 84,870,208.81	$ -
Vegetable & Melon					
Cantaloupe (cwt)	$ 0.56	3.64	$ 10,739,304.75	$ 1,303,539.78	$ 9,435,764.97
Carrot (cwt)	$ 0.15	0.63	$ -1,884,535.80	$ -2,830,857.66	$ 946,321.86
Honeydew (cwt)	$ 0.71	4.30	$ 2,743,931.39	$ 946,975.92	$ 1,796,955.46
Lettuce (cwt)	$ 4.33	20.20	$ 198,206,266.85	$ 111,700,356.46	$ 86,505,910.39
Spinach (cwt)	$ 17.41	51.30	$ 70,382,598.89	$ 32,842,430.62	$ 37,540,168.28
Tomato- Fresh (cwt)	$ 0.87	2.23	$ 5,180,352.83	$ -19,453,093.50	$ 24,633,446.32
Tomato-Proc (tons)	$ 7.56	10.19	$ -43,815,200.93	$ -10,946,350.70	$ 5,762,486.00
Watermelon (cwt)	$ 0.14	1.01	$ 5,103,478.50	$ -3,817,806.82	$ 8,921,285.32

Consumers and producers were both shown to benefit from the increased supply and lower wholesale prices realized through the use of pest controls by California growers. Control practices minimizing bird damage were estimated to prevent approximately $2.15 billion in losses to consumers nationwide, with consumers realizing approximately $3.74 billion of benefits from controlling rodent damage. Current controls to mitigate rodent crop damage were forecasted to prevent $938 million in losses to California producers of these select crops, with another $586 million in losses prevented through bird controls. Results indicated that the U.S.

benefited by more than $2 billion from California bird control and by nearly $3 billion from California rodent control in the short run. Tables 13 and 14 show changes in consumer and producer surpluses for individual crops.

Table 13: Short-Run Welfare implications of Rodent Control Removal

Crop	Consumer Surplus	CA Producer Surplus	Outside-CA Producer Surplus	Net Change in US Welfare
Fruit				
Avocado (tons)	$ -36,683,012.83	$ -5,264,194.87	$ 3,847.44	$ -41,943,360.26
Cherries (tons)	$ -25,046,858.87	$ -17,918,233.26	$ 18,963,766.43	$ -24,001,325.69
Grapes-Raisin (tons)	$ -36,578,906.23	$ -21,570,855.36	$ -	$ -58,149,761.60
Grapes-Table (tons)	$ -44,344,857.05	$ -29,196,770.89	$ 3,840,746.65	$ -69,700,881.29
Grapes-Wine (tons)	$ -363,780,768.18	$ -72,814,111.51	$ 76,187,039.95	$ -360,407,839.75
Lemon (box=76lbs)	$ -61,197,495.11	$ -41,744,918.74	$ 6,657,838.11	$ -96,284,575.74
Oranges (box=75lbs)	$ -77,104,389.69	$ -92,978,417.89	$ 57,989,389.85	$ -112,093,417.73
Peach (tons)	$ -44,649,779.35	$ -36,311,629.75	$ 11,094,925.78	$ -69,866,483.33
Strawberries (cwt)	$ -168,553,944.52	$ -160,115,345.44	$ 103,089,827.98	$ -225,579,461.98
Grain				
Rice (cwt)	$ -60,915,406.01	$ -36,496,309.27	$ 48,273,504.49	$ -49,138,210.79
Hay				
Alfalfa (tons)	$ -1,411,180,466.38	$ -311,625,376.59	$ 1,264,254,638.60	$ -458,551,204.36
Tree Nuts				
Almonds (lbs)	$ -529,363,813.53	$ 3,146,246.29	$ -	$ -526,217,567.23
Pistachios (lbs)	$ -30,729,469.21	$ -26,042,919.43	$ -	$ -56,772,388.64
Walnuts (tons in shell)	$ -367,569,612.34	$ 187,542,866.36	$ -	$ -180,026,745.98
Vegetable & Melon				
Cantaloupe (cwt)	$ -17,661,902.69	$ -7,792,342.86	$ 7,563,693.51	$ -17,890,552.04
Carrot (cwt)	$ -42,143,887.51	$ -58,378,679.84	$ 7,749,816.41	$ -92,772,750.94
Honeydew (cwt)	$ -4,505,005.25	$ -1,524,592.37	$ 1,440,463.42	$ -4,589,134.20
Lettuce (cwt)	$ -140,065,264.78	$ 28,149,714.90	$ 35,494,397.47	$ -76,421,152.42
Spinach (cwt)	$ 4,379.96	$ 1,734.80	$ -985.90	$ 5,128.86
Tomato- Fresh (cwt)	$ -49,799,502.15	$ -39,174,104.73	$ 33,545,188.12	$ -55,428,418.77
Tomato-Proc (tons)	$ -218,671,000.66	$ -191,112,746.90	$ 11,901,610.05	$ -397,882,137.51
Watermelon (cwt)	$ -8,411,448.77	$ -7,033,558.23	$ 7,114,998.52	$ -8,330,008.48

Table 14: Short-Run Welfare implications of Bird Control Removal

Crop	Consumer Surplus	CA Producer Surplus	Outside-CA Producer Surplus	Net Change in US Welfare
Fruit				
Avocado (tons)	$ -7,371,675.25	$ -98,840.14	$ 743,608.51	$ -6,726,906.89
Cherries (tons)	$ -32,512,589.64	$ -23,565,275.83	$ 24,734,243.59	$ -31,343,621.87
Grapes-Raisin (tons)	$ -28,509,692.99	$ -16,095,206.11	$ -	$ -44,604,899.10
Grapes-Table (tons)	$ -91,638,690.34	$ -70,730,915.04	$ 8,408,707.44	$ -153,960,897.95
Grapes-Wine (tons)	$ -672,566,463.62	$ -184,707,839.41	$ 149,001,765.92	$ -708,272,537.11
Lemon (box=76lbs)	$ -7,231,181.28	$ -3,802,380.54	$ 730,349.24	$ -10,303,212.57
Oranges (box=75lbs)	$ -8,872,046.59	$ -10,188,038.74	$ 6,530,663.54	$ -12,529,421.79
Peach (tons)	$ -70,712,806.62	$ -63,306,645.69	$ 18,478,217.36	$ -115,541,234.95
Strawberries (cwt)	$ -133,926,734.17	$ -128,583,810.69	$ 81,354,474.19	$ -181,156,070.67
Grain				
Rice (cwt)	$ -108,284,369.23	$ -65,848,879.43	$ 86,221,949.71	$ -87,911,298.95
Hay				
Alfalfa (tons)	$ -165,905,705.15	$ -30,229,320.97	$ 145,887,057.86	$ -50,247,968.26
Tree Nuts				
Almonds (lbs)	$ -171,236,372.11	$ 22,254,089.91	$ -	$ -148,982,282.20
Pistachios (lbs)	$ -40,894,177.58	$ -36,079,201.11	$ -	$ -76,973,378.69
Walnuts (tons in shell)	$ -133,591,679.53	$ 81,825,116.89	$ -	$ -51,766,562.63
Vegetable & Melon				
Cantaloupe (cwt)	$ -11,136,432.16	$ -4,952,911.83	$ 4,717,882.49	$ -11,371,461.50
Carrot (cwt)	$ -3,681,860.27	$ -4,370,552.58	$ 630,551.42	$ -7,421,861.42
Honeydew (cwt)	$ -2,845,751.62	$ -968,757.84	$ 898,477.73	$ -2,916,031.73
Lettuce (cwt)	$ -245,178,533.55	$ 41,293,321.82	$ 63,517,794.84	$ -140,367,416.89
Spinach (cwt)	$ -90,782,919.13	$ -13,380,615.65	$ 24,113,155.37	$ -80,050,379.41
Tomato- Fresh (cwt)	$ -28,999,827.00	$ -22,171,759.45	$ 19,362,971.87	$ -31,808,614.58
Tomato-Proc (tons)	$ -85,269,995.75	$ -47,867,376.49	$ 4,052,175.57	$ -129,085,196.68
Watermelon (cwt)	$ -5,289,578.63	$ -4,497,179.45	$ 4,460,642.66	$ -5,326,115.42

In the long run factors of production are not fixed, implying that producers can more readily change inputs in response to changes in yield per acre and prices. Increased pest damage was shown to reduce production and raise prices in the short run. Results indicated that in the long run producers would compensate reduced yields by increasing harvested acres, causing long run production to be slightly higher than in the short run. This is especially true for California's many perennial crops, such as oranges, lemons, and wine grapes which can take several growing seasons to become crop bearing. Tables 15 and 16 summarize long run changes in production for individual crops.

Table 15: Long-Run Production Changes without Rodent Control

Crop	% Yield Loss Without Control	CA Production (Units)	Outside-CA Production (Units)	Net Change in US Supply (Units)
Fruit				
Avocado (tons)	9.63	-13,859	752	-13,107
Cherries (tons)	13.06	-6,990	5,811	-1,179
Grapes-Raisin (tons)	12.33	-70,588	0	-70,588
Grapes-Table (tons)	11.20	-38,550	4,756	-33,795
Grapes-Wine (tons)	17.58	-153,394	92,757	-60,637
Lemon (box=76lbs)	18.44	-840,707	257,409	-583,299
Oranges (box=75lbs)	18.44	-7,008,758	5,354,732	-1,654,026
Peach (tons)	21.03	-87,598	26,130	-61,468
Strawberries (cwt)	16.47	-2,407,722	1,650,731	-756,991
Grain				
Rice (cwt)	5.83	-1,983,907	1,738,631	-245,276
Hay				
Alfalfa (tons)	34.52	-2,385,495	957,729	-1,427,766
Tree Nuts				
Almonds (lbs)	18.86	-11,802,483	0	-11,802,483
Pistachios (lbs)	9.61	-12,984,698	0	-12,984,698
Walnuts (tons in shell)	20.51	-60,617	0	-60,617
Vegetable & Melon				
Cantaloupe (cwt)	10.36	-503,692	476,928	-26,764
Carrot (cwt)	18.37	-2,470,349	251,717	-2,218,632
Honeydew (cwt)	10.36	-91,244	84,835	-6,409
Lettuce (cwt)	7.77	-1,681,601	552,553	-1,129,048
Spinach (cwt)	-	32	-13	19
Tomato- Fresh (cwt)	12.30	-1,233,868	304,613	-929,255
Tomato-Proc (tons)	41.50	-2,806,717	86,558	-2,720,159
Watermelon (cwt)	10.36	-541,698	527,039	-14,659

Table 16: Long-Run Production Changes without Bird Control

Crop	% Yield Loss Without Control	CA Production (Units)	Outside-CA Production (Units)	Net Change in US Supply (Units)
Fruit				
Avocado (tons)	1.74	-2,459	147	-2,312
Cherries (tons)	16.50	-9,259	7,697	-1,562
Grapes-Raisin (tons)	15.61	-70,591	0	-70,591
Grapes-Table (tons)	16.23	-55,447	6,840	-48,607
Grapes-Wine (tons)	32.75	-287,259	173,705	-113,553
Lemon (box=76lbs)	2.07	-97,163	29,749	-67,413
Oranges (box=75lbs)	2.07	-870,187	664,828	-205,359
Peach (tons)	34.10	-142,423	42,484	-99,939
Strawberries (cwt)	13.27	-1,897,359	1,299,662	-597,698
Grain				
Rice (cwt)	10.41	-3,528,325	3,092,109	-436,216
Hay				
Alfalfa (tons)	4.00	-277,489	111,406	-166,083
Tree Nuts				
Almonds (lbs)	5.75	-3,761,532	0	-3,761,532
Pistachios (lbs)	12.88	-17,469,843	0	-17,469,843
Walnuts (tons in shell)	6.96	-20,579	0	-20,579
Vegetable & Melon				
Cantaloupe (cwt)	6.49	-318,397	301,479	-16,918
Carrot (cwt)	1.52	-205,196	20,909	-184,288
Honeydew (cwt)	6.49	-57,832	53,770	-4,062
Lettuce (cwt)	13.70	-2,965,980	974,584	-1,991,396
Spinach (cwt)	44.44	-634,573	360,619	-273,953
Tomato- Fresh (cwt)	7.09	-715,119	176,546	-538,573
Tomato-Proc (tons)	14.63	-992,760	30,616	-962,144
Watermelon (cwt)	6.49	-341,184	331,951	-9,233

When long run results in tables 17 and 18 are compared to those in the short run we see that the positive impacts of pest control on prices diminish in the long run. Current rodent control practices were estimated to reduce wholesale prices for these select crops between 0 to 60.30 percent lower in the short run and between 0 and 51.2 percent lower in the long run, with bird controls maintaining 0.39 to 51.30 percent lower prices in the short run and 0.38 to 29.38 percent lower prices in the long run.

Table 17: Long-Run Effects of Rodent Control Removal on Farm Revenue

Crop	Change in Price	% Change in Price	Consumer Expenditure	CA Total Revenue	Outside-CA Total Revenue
Fruit					
Avocado (tons)	$ 173.68	9.87	$ 12,473,783.27	$ 7,237,292.51	$ 5,236,490.76
Cherries (tons)	$ 56.55	2.20	$ 12,956,176.53	$ -14,291,608.46	$ 27,247,784.99
Grapes-Raisin (tons)	$ 17.67	6.10	$ 6,275,962.23	$ 6,275,962.23	$ -
Grapes-Table (tons)	$ 37.71	5.14	$ 7,843,088.32	$ 1,387,720.81	$ 6,455,367.51
Grapes-Wine (tons)	$ 58.89	9.57	$ 192,322,141.31	$ 84,118,834.48	$ 108,203,306.83
Lemon (box=76lbs)	$ 0.91	3.26	$ 1,137,943.22	$ -8,066,511.57	$ 9,204,454.79
Oranges (box=75lbs)	$ 0.10	0.88	$ 1,708,184.27	$ -72,562,932.60	$ 74,271,116.87
Peach (tons)	$ 31.58	8.39	$ 9,244,275.27	$ -9,276,380.56	$ 18,520,655.82
Strawberries (cwt)	$ 2.34	3.48	$ 72,399,080.13	$ -116,490,763.11	$ 188,889,843.23
Grain					
Rice (cwt)	$ 0.31	1.54	$ 56,001,584.92	$ -27,103,434.64	$ 83,105,019.56
Hay	$ -				
Alfalfa (tons)	$ 23.88	14.04	$ 115,226,920.90	$ -287,221,355.02	$ 1,438,556,138.93
Tree Nuts					
Almonds (lbs)	$ 0.02	1.24	$ 9,042,131.23	$ 9,042,131.23	$ -
Pistachios (lbs)	$ 0.08	4.18	$ -1,018,052.88	$ -1,018,052.88	$ -
Walnuts (tons in shell)	$ 933.46	51.20	$ 178,274,357.75	$ 178,274,357.75	$ -
Vegetable & Melon					
Cantaloupe (cwt)	$ 0.60	3.87	$ 11,419,915.34	$ -1,185,302.56	$ 12,605,217.90
Carrot (cwt)	$ 1.46	6.05	$ -21,050,142.26	$ -33,544,089.95	$ 12,493,947.69
Honeydew (cwt)	$ 0.75	4.56	$ 2,907,341.33	$ 513,546.31	$ 2,393,795.02
Lettuce (cwt)	$ 2.45	11.45	$ 114,491,845.87	$ 66,481,878.05	$ 48,009,967.82
Spinach (cwt)	$ -	0.00	$ -3,168.33	$ -1,877.91	$ -1,290.42
Tomato- Fresh (cwt)	$ 1.33	3.43	$ 7,521,208.10	$ -34,379,312.84	$ 41,900,520.93
Tomato-Proc (tons)	$ 17.72	23.89	$ -39,810,825.98	$ -57,074,481.59	$ 17,263,655.61
Watermelon (cwt)	$ 0.15	1.08	$ 5,453,793.07	$ -6,480,443.84	$ 11,934,236.91

Table 18: Long-Run Effects of Bird Control Removal on Farm Revenue

Crop	Change in Price	% Change in Price	Consumer Expenditure	CA Total Revenue	Outside-CA Total Revenue
Fruit					
Avocado (tons)	$ 34.03	2.00	$ 3,263,697.63	$ 2,258,196.20	$ 1,005,501.44
Cherries (tons)	$ 74.90	2.91	$ 17,133,270.31	$ -19,100,843.63	$ 36,234,113.94
Grapes-Raisin (tons)	$ 17.67	7.77	$ 6,276,159.65	$ 6,276,159.65	$ -
Grapes-Table (tons)	$ 54.25	7.40	$ 10,477,244.74	$ 1,079,397.22	$ 9,397,847.52
Grapes-Wine (tons)	$ 110.28	17.92	$ 354,324,112.98	$ 142,766,307.52	$ 211,557,805.47
Lemon (box=76lbs)	$ 0.10	0.38	$ 185,642.79	$ -854,252.52	$ 1,039,895.30
Oranges (box=75lbs)	$ 0.01	0.11	$ 229,538.66	$ -8,935,241.71	$ 9,164,780.37
Peach (tons)	$ 51.35	13.65	$ 13,054,581.84	$ -17,897,239.64	$ 30,951,821.49
Strawberries (cwt)	$ 1.85	2.75	$ 57,458,924.73	$ -90,617,767.98	$ 148,076,692.71
Grain					
Rice (cwt)	$ 0.55	2.74	$ 99,493,239.34	$ -49,044,445.64	$ 148,537,684.98
Hay					
Alfalfa (tons)	$ 2.78	1.63	$ 137,431,856.47	$ -27,555,132.16	$ 164,986,988.63
Tree Nuts					
Almonds (lbs)	$ 0.01	0.39	$ 2,940,201.82	$ 2,940,201.82	$ -
Pistachios (lbs)	$ 0.11	5.62	$ -1,842,827.22	$ -1,842,827.22	$ -
Walnuts (tons in shell)	$ 316.91	17.38	$ 73,212,264.06	$ 73,212,264.06	$ -
Vegetable & Melon					
Cantaloupe (cwt)	$ 0.38	2.45	$ 7,222,567.01	$ -678,940.74	$ 7,901,507.74
Carrot (cwt)	$ 0.12	0.50	$ -1,502,047.11	$ -2,511,879.27	$ 1,009,832.16
Honeydew (cwt)	$ 0.48	2.89	$ 1,843,842.37	$ 341,402.86	$ 1,502,439.51
Lettuce (cwt)	$ 4.33	20.20	$ 198,206,266.85	$ 111,700,356.46	$ 86,505,910.39
Spinach (cwt)	$ 9.97	29.38	$ 42,345,683.74	$ 14,270,472.10	$ 28,075,211.64
Tomato- Fresh (cwt)	$ 0.77	1.99	$ 4,661,155.69	$ -19,524,333.54	$ 24,185,489.22
Tomato-Proc (tons)	$ 6.27	8.45	$ -3,058,431.72	$ -8,813,975.39	$ 5,755,543.67
Watermelon (cwt)	$ 0.09	0.68	$ 3,435,521.24	$ -4,063,306.65	$ 7,498,827.89

Results from these models indicated that U.S. producers and consumers benefitted in the short and the long run from the effective use of current pest management practices in California. The use of rodent controls was shown to prevent $2.8 billion in losses to consumers nationwide and $589 million in foregone lossses to California growers in the long run, protecting an estimated $1.83 billion in net social benefits. California production practices designed to control bird damage were shown to protect producers of these select crops in California from an estimated $457 million in losses and U.S. consumers from $1.5 billion in losses in the long run, providing an additional $1.42 billion in net social benefits in the long run. Tables 19 and 20 provide estimated surplus changes for individual crops.

Table 19: Long-Run Welfare Implications of Rodent Control Removal

Crop	Consumer Surplus	CA Producer Surplus	Outside-CA Producer Surplus	Net Change in US Welfare
Fruit				
Avocado (tons)	$ -36,683,012.83	$ -5,264,194.87	$ 3,847.44	$ -41,943,360.26
Cherries (tons)	$ -16,024,439.20	$ -13,697,183.83	$ 12,128,382.07	$ -17,593,240.96
Grapes-Raisin (tons)	$ -27,343,117.98	$ -15,990,256.01	$ -	$ -43,333,373.99
Grapes-Table (tons)	$ -33,257,306.69	$ -22,082,453.99	$ 2,879,016.58	$ -52,460,744.09
Grapes-Wine (tons)	$ -231,420,397.20	$ -73,694,566.57	$ 48,393,811.11	$ -256,721,152.65
Lemon (box=76lbs)	$ -17,665,222.75	$ -5,721,194.56	$ 1,910,997.31	$ -21,475,420.00
Oranges (box=75lbs)	$ -20,013,341.96	$ -18,077,679.94	$ 15,010,124.01	$ -23,080,897.90
Peach (tons)	$ -33,340,808.81	$ -24,986,383.11	$ 8,277,248.37	$ -50,049,943.55
Strawberries (cwt)	$ -124,194,235.95	$ -101,983,779.48	$ 75,942,813.11	$ -150,235,202.33
Grain				
Rice (cwt)	$ -60,915,406.01	$ -36,496,309.27	$ 48,273,504.49	$ -49,138,210.79
Hay				
Alfalfa (tons)	$ -1,411,180,466.38	$ -311,625,376.59	$ 1,264,254,638.60	$ -458,551,204.36
Tree Nuts				
Almonds (lbs)	$ -30,902,661.01	$ -1,802,655.23	$ -	$ -32,705,316.24
Pistachios (lbs)	$ -23,848,497.06	$ -19,078,797.65	$ -	$ -42,927,294.71
Walnuts (tons in shell)	$ -317,087,448.60	$ 143,571,085.04	$ -	$ -173,516,363.57
Vegetable & Melon				
Cantaloupe (cwt)	$ -11,842,725.87	$ -5,090,418.90	$ 5,070,720.15	$ -11,862,424.62
Carrot (cwt)	$ -34,010,632.79	$ -55,880,358.60	$ 6,246,973.84	$ -83,644,017.55
Honeydew (cwt)	$ -3,015,370.87	$ -985,970.95	$ 963,890.71	$ -3,037,451.10
Lettuce (cwt)	$ -140,065,264.78	$ 28,149,714.90	$ 35,494,397.47	$ -76,421,152.42
Spinach (cwt)	$ 3,821.86	$ -397.14	$ -860.28	$ 2,564.44
Tomato- Fresh (cwt)	$ -44,307,411.34	$ -40,599,520.32	$ 29,841,869.66	$ -55,065,062.00
Tomato-Proc (tons)	$ -186,115,962.68	$ -2,952,346.81	$ 10,074,451.70	$ -178,993,857.79
Watermelon (cwt)	$ -5,652,740.95	$ -4,664,393.30	$ 4,781,350.59	$ -5,535,783.66

Table 20: Long-Run Welfare Implication of Bird Control Removal

Crop	Consumer Surplus	CA Producer Surplus	Outside-CA Producer Surplus	Net Change in US Welfare
Fruit				
Avocado (tons)	$ -7,371,675.25	$ -98,840.14	$ 743,608.51	$ -6,726,906.89
Cherries (tons)	$ -21,211,873.32	$ -17,844,720.70	$ 16,136,081.66	$ -22,920,512.36
Grapes-Raisin (tons)	$ -15,990,869.43	$ -15,990,869.43	$ -	$ -31,981,738.86
Grapes-Table (tons)	$ -27,738,439.22	$ -31,428,137.11	$ 4,197,434.56	$ -54,969,141.77
Grapes-Wine (tons)	$ -430,460,725.80	$ -135,035,073.42	$ 95,089,888.55	$ -470,405,910.67
Lemon (box=76lbs)	$ -2,068,677.82	$ -675,378.32	$ 208,915.47	$ -2,535,140.67
Oranges (box=75lbs)	$ -2,493,527.21	$ -2,378,099.29	$ 1,835,359.28	$ -3,036,267.22
Peach (tons)	$ -53,219,987.94	$ -39,221,286.56	$ 13,877,555.63	$ -78,563,718.87
Strawberries (cwt)	$ -98,207,449.71	$ -81,377,664.06	$ 59,471,177.72	$ -120,113,936.05
Grain				
Rice (cwt)	$ -108,284,369.23	$ -65,848,879.43	$ 86,221,949.71	$ -87,911,298.95
Hay				
Alfalfa (tons)	$ -165,905,705.15	$ -30,229,320.97	$ 145,887,057.86	$ -50,247,968.26
Tree Nuts				
Almonds (lbs)	$ -9,878,094.84	$ -576,222.20	$ -	$ -10,454,317.04
Pistachios (lbs)	$ -31,849,629.96	$ -25,479,703.97	$ -	$ -57,329,333.93
Walnuts (tons in shell)	$ -113,995,075.27	$ 63,016,561.26	$ -	$ -50,978,514.01
Vegetable & Melon				
Cantaloupe (cwt)	$ -7,487,968.49	$ -3,244,217.83	$ 3,172,044.38	$ -7,560,141.95
Carrot (cwt)	$ -2,948,278.98	$ -4,917,795.42	$ 504,916.08	$ -7,361,158.32
Honeydew (cwt)	$ -1,911,754.71	$ -628,748.84	$ 603,535.88	$ -1,936,967.66
Lettuce (cwt)	$ -245,178,533.55	$ 41,293,321.82	$ 63,517,794.84	$ -140,367,416.89
Spinach (cwt)	$ -53,009,695.76	$ -19,920,805.45	$ 14,037,605.82	$ -58,892,895.40
Tomato- Fresh (cwt)	$ -25,830,501.34	$ -23,103,874.52	$ 17,246,100.69	$ -31,688,275.17
Tomato-Proc (tons)	$ -71,342,348.51	$ -59,922,033.05	$ 3,388,040.53	$ -127,876,341.02
Watermelon (cwt)	$ -3,560,578.63	$ -2,986,927.72	$ 3,002,568.22	$ -3,544,938.13

3. 3: REMI Results

Responses from the CA producer survey indicated that eliminating pest control practices would significantly affect yields for many of the state's high value crops, and the partial equilibrium model measured changes in the markets for select California crops without these additional crop savings. To further examine the secondary effects of reported crop savings, results from the partial equilibrium model were used as exogenous shocks in the REMI model.

It is important to note that REMI results are reported as the difference between two forecasts; a baseline forecast with projections of what California's economy would look like if current trends continued, and a simulation forecast where policy variables are changed to reflect changes in the state's economic environment. Since the benefits of pest control are equal to the damage they prevent, benefits of control can be estimated by modeling the additional losses producers would incur in the absence of these practices. To examine the contributions of these additional crop savings, results from the partial equilibrium model were aggregated into five types of crops: fruit (avocados, cherries, oranges, lemons, raisin grapes, table grapes, wine grapes, peaches, and strawberries), nut (almonds, pistachios, and walnuts), grain (rice), vegetable and melon (carrots, lettuce, cantaloupe, honeydew, spinach, fresh tomatoes, processing tomatoes, and watermelons), and all other crops (alfalfa hay); and entered into REMI as changes in output and proprietor's income in the farm sector over the ten year period.

Key economic indicators were identified and analyzed to provide estimates for changes in employment, income, and production. Measurements of total and private non-farm employment can be interpreted as the number of jobs, or opportunities for which an individual can gain employment for 1 year, and makes no distinction between full-time and part-time employment. Gross Domestic Product (GDP) and Output are both presented as measurements of productivity, but only GDP will be discussed so that we avoid the "double counting" of intermediate goods. Real Disposable Income and Population were two additional variables identified as reflecting the overall health of California's economy. Forecasted changes in these economic indicators will then be presented in four ways; their current contributions to California's economy in 2012, their average annual contribution over a short-run five year period, average annual contributions in the long-run (or next five years), and the cumulative contributions of bird and rodent pest control over the ten year period discounted using a 2.5 percent discount rate. Discounting cumulative benefits accounts for time preferences which reduce the value of benefits accrued over time. All estimates are reported in 2012 US dollars.

3.3.1 Changes in Output

If California producers were no longer able to control for bird or rodent damage, yield losses would increase and output from producers would decline. To examine the contributions of these crop savings, changes in market output for select California crops were estimated as the difference between original prices and quantities and new market output at original price levels. Since the partial equilibrium model included in-state and out-of-state firms, avoided losses were entered as changes in fruit, nut, grain, vegetable and melon, and all other crop farming within California and throughout the rest of the country.

Rodent damage to crops was the most widely reported form of damage by California producers, and results indicate that the use of pest controls to deter rodent activity contributes significantly to the economic health of the entire state. Key findings from the simulation with reduced crop savings are summarized in Table 21.

Table 21: Economic Contributions of Rodent Crop Savings and Impacts of Control Removal

Economic Indicator	Current Contributions	Short-Run Savings (Years 1-5)	Long-Run Savings (Years 6-10)	Discounted 10 Year Savings
Population	5,094	11,842	21,084	---
Total Employment	23,000	22,449	17,548	---
Private Non-Farm Employment	11,607	11,330	8,827	---
Gross Domestic Product	$ 1,728,370,138	$ 1,749,807,287	$ 1,517,794,810	$ 693,860,520
Output	$ 4,163,496,282	$ 3,320,525,058	$ 2,889,549,042	$ 1,318,132,944
Real Disposable Personal Income	$ 1,179,043,195	$ 937,651,965	$ 904,603,027	$ 358,039,436

This analysis found that the production and sale of additional yields protected by rodent control contributed $1.73 billion to the California economy, supported 23,000 jobs, and increased real disposable personal income within the state by more than $773 million. If producers no longer controlled for rodent damage, the loss of these additional yields would significantly affect the economic climate within the state. Without these crop savings California GDP is estimated to fall by $1.4 billion over the first 5 years, costing the state 22,449 jobs and more than $937 million in unrealized personal income. Production changes over the long run would enable California to recover slightly from these losses, but the elimination of rodent control would still be expected to cost the state more than $1.5 billion in lost productivity over the next five year period. During this period, 17,548 California jobs and $904 million of disposable income will be lost. Over a ten year period a prohibition on rodent control could potential cost California $693 million in lost productivity, $358 million in unrealized disposable income when average annual losses are discounted using a 2.5% discount rate.

To estimate the benefits of California yield protected through current bird control practices, another simulation was run and compared to the baseline forecast of current economic contributions. Similar to the simulation for rodent control, this simulation modeled a complete removal of bird specific control so that avoided losses could be examined.

Table 22: Economic Contributions of Current Bird Crop Savings and Impacts of Control Removal

Economic Indicator	Current Contributions	Short-Run Savings (Years 1-5)	Long-Run Savings (Years 6-10)	Discounted 10 Year Savings
Population	4,512	10,482	17,967	--
Total Employment	20,217	19,728	14,110	--
Private Non-Farm Employment	9,572	9,344	6,588	--
Gross Domestic Product	$ 1,393,414,685	$ 1,411,502,279	$ 1,101,556,833	$ 559,460,330
Output	$ 2,534,496,262	$ 2,564,418,949	$ 2,005,713,253	$ 1,017,463,641
Real Disposable Personal Income	$ 773,747,096	$ 817,514,609	$ 725,066,904	$ 312,010,589

Results in table 22 suggest that the protected yields significantly contributed to current economic conditions in California, and that the loss of these savings would cost the state billions in unrealized income and revenue. Yields protected by current practices were estimated to contribute $1.39 billion to the state's GDP and were shown to support 20,217 California jobs. If the state's growers were prohibited from controlling bird damage California could lose 8,056 jobs and $312 million disposable income, resulting in a productivity decrease of $559 million over a ten year period.Similar to the results from the rodent simulation, the economic impacts of losing these crop savings would be more significant in the short run, with the state suffering substantial losses in the long run.

The negative impacts of reduced farm output would not be isolated to the farm sector. Simulation results indicated that approximately half of the lost employment opportunities in California would be in private non-farm sectors. Results from the both simulations indicated that the state's population would decrease as a result of changes in agricultural production. As employment and income within the state fell, the model indicated that many residents would immigrate to regions with more a favorable economic climate. Although it was not examined in this study, emigration could negatively impact California property values and tax bases.

3.3.2 Changes in Proprietor's Income

In addition to the economic activity associated with the production of these additional yields, their sale increases proprietors' income and stimulates consumption by producers. Results from the partial equilibrium model illustrated how farm revenue and producer surpluses would significantly fall with the absence of these crop savings. To examine the contributions of these additional expenditures, we modeled the expected loss in producer surplus over a ten year period when these yields were not produced. The change in producer surplus was estimated as the difference between the change in total revenue and the change in total variable costs for California producers incurring higher yield losses without the use of control measures. Since most farm operations are considered sole proprietorships, results from this simulation indicate that the potential losses in agricultural income could significantly affect California's economic climate.

The yields protected through current rodent control practices generated an additional $978 million in farm income. The purchases made with this additional income were estimated to contribute more than $950 million to the value of the state's economy and support 11,374 California jobs. If California growers no longer controlled for rodent damage, consumption stimulated by income earned crop savings would be lost. Reduced consumption resulting from unrealized crop savings would cost California's economy more than $943 million annually in lost productivity over the first five years. Reduced consumption and production within the state during this period would cost California 10,862 jobs and approximately $1.23 billion in unrealized income.

Table 23: Economic Contributions of Rodent Crop Savings and Impacts of Control Removal

Economic Indicator	Current Contributions	Average Savings (Years 1-5)	Average Savings (Years 6-10)	Discounted 10 Year Savings
Population	2,576	5,558	9,037	--
Total Employment	11,374	10,862	7,390	--
Private Non-Farm Employment	10,428	9,926	6,687	--
Gross Domestic Product	$ 950,905,084.42	$ 943,541,881.33	$ 720,542,016.40	$ 379,828,978.30
Output	$ 1,552,583,965.27	$ 1,536,805,672.94	$ 1,152,236,094.55	$ 620,270,889.83
Real Disposable Personal Income	$ 1,249,640,752.53	$ 1,227,971,897.73	$ 1,011,493,726.97	$ 495,692,507.19

The economic activity associated with the $603 million earned from the sale of yields protected by bird control was shown to contribute over $565 million to the state's GDP and support 6,775 California jobs, 6,215 of which are supported in private non-farm sectors. Without these consumption expenditures, California's economy would contract by $560 million during the first five years, costing California 6,461 jobs and $745 million in unrealized personal income. In the long-run resources would be reallocated, allowing economic conditions to improve slightly, but California production would still be worth nearly $399 million less and support 4,102 fewer annual jobs than forecasts which included farm income on protected yields.

Table 24: Economic Contributions of Bird Crop Savings and Impacts of Control Removal

Economic Indicator	Current Contributions	Short-Run Savings (Years 1-5)	Long-Run Savings (Years 6-10)	Discounted 10 Year Savings
Population	1,463	3,134	4,932	--
Total Employment	6,775	6,461	4,102	--
Private Non-Farm Employment	6,215	5,907	3,714	--
Gross Domestic Product	$ 565,914,751.57	$ 560,655,320.79	$ 399,085,607.33	$ 225,942,045.28
Output	$ 922,504,158.22	$ 911,774,919.44	$ 636,391,123.97	$ 368,321,860.96
Real Disposable Personal Income	$ 759,461,804.15	$ 745,366,529.67	$ 579,799,648.82	$ 301,124,468.02

CHAPTER 4: CONCLUSION and DISCUSSION

4.1 Summary of Findings

California is the top agriculture producing state in the country with production valued in excess of $37 billion. Production by California growers accounts for nearly half of all fruits, nuts, and vegetables grown in the U.S and earns 16% of national crop revenue (CDFA 2010, CDFA 2011). Although California's agriculture sector only accounts for a small percentage of the state's overall output, it is a vital segment of California's diverse economy. In addition to contributing economic activity and employment to the state's economy, the agriculture sector also provides inputs to nearly all other sectors of the economy.

Bird and rodent damage has been estimated to cost producers millions in yield losses and damage to farm equipment. Since California produces such a large share of the U.S. supply of fruits, nuts, and vegetables, these yield losses can have broad economic impacts which negatively affect the state's economy and consumers throughout the U.S. and around the world. Although producers have adopted integrated pest management as an essential part of crop production in order to mitigate bird and rodent damage, increasing regulations within California threaten producers' ability to effectively control pest damage. The prohibition of some well-established practices with proven efficacy has increased production costs within the state and made it more difficult for California crops to compete in global markets.

California producers reported using a wide variety of tools to control bird and rodent damage, spending on average $11.61 an acre on rodent control and $8.21 an acre on bird control.

Even with these controls more than 80 percent of producers reported suffering yield losses from rodents and nearly half reported losses from birds. Reports also indicated that bird and rodent damage would significantly increase in the absence of control, which attests to the efficacy of current control practices. This study found that current California control practices as applied to alfalfa, almonds, avocados, carrots, cherries, citrus, grapes, lettuce, melons, peaches, pistachios, rice, strawberries, tomatoes, and walnuts were effective at mitigating crop loss which had the potential to significantly restrict the domestic supply of these agricultural commodities. These practices were shown to lower wholesale prices and were estimated to prevent multi-million dollar losses to California growers, and multi-billion dollar losses to consumers nationwide.

In addition to the direct benefits realized through these crop savings, the production and sale of these additional yields further stimulates economic activity within the state. Modeling the forward and backward linakages between California suppliers and consumers enabled monetary flows in secondary markets to be quantified, providing a more conclusive estimate of the total benefits of bird and rodent control in California. This study found that expenditures related to the production of additional yields protected from rodent damage contributed $1.7 billion to California's economy and supported 23,000 jobs, with farm revenue earned on these yields supporting another 11,000 California jobs and contributing nearly $951 millionto the state's economy. Findings from this study also estimated that the production of yields protected from bird damage were estimated to contribute $1.39 billion to the state's economy and supported more than 20,000 jobs, with farm revenue earned on these yields supporting another 6,775 jobs and contributing another $565 million to California's economy.

This study was intended to add to the body of literature pertaining to vertebrate pest damage by examining the direct financial and welfare impacts of increased food production, lower production costs and market prices associated with current bird and rodent pest control practices for select California crops. In addition to estimating the direct effects of California pest control use, this study quantified the secondary effects of the yields protected through these practices so the total economic contributions of these crop savings could be measured and economic impacts of control removal could be examined. Although the small, non-random samples used to estimate economic contributions of current bird and rodent control and economic impacts associated with control removal likely produced biased results which may not be representative of agricultural damage to these select crops, results from this study highlight the social and economic importance of agricultural pest control in California.

As California’s stringent environmental regulations continue to restrict pesticide use in the state, it is critical that policy makers understand that producers’ ability to mitigate pest damage has economic impacts and benefits which extend well beyond the profit margins of California producers. Any regulation that affects the cost or efficacy of agricultural pest control will impose costs on producers which can translate in to reduced market supply and increased market prices. Higher wholesale prices for agricultural goods will directly affect processing and grocery industries which rely on California crops for final products, translating into higher retail prices for households.

4.2 Limitations

Like any study, the analysis conducted in this study is only as good as the data and models on which it relies. This study utilized sound methodologies to analyze both the micro and macroeconomic contributions of bird and rodent pest control in California in order to provide insight into an important gap in the agricultural pest literature. These benefits, or avoided losses, provided by pest control have long been ignored in previous research. Measurements of the economic contributions of California bird and rodent control provided by this study where estimated based on a limited number of producer responses, which may bias the results.

Since there were no prior estimates of multi-crop yield savings in California, data collection was a crucial component of this study. Although the ideal sample frame for this study would have been all California producers of these select crops, obtaining contact information for thousands of the state's growers would have been an impossible task. Collaboration with a large farm organization like the California Farm Bureau Federation provided the contact information needed to distribute the survey to thousands of agricultural producers in California, but may have excluded smaller operations which have not paid the fees to gain membership. Since Farm Bureau's member listserv includes all producers and does not distinguish between commodity production, survey links had to be sent out to everyone to ensure that the target subgroup of members received the link. This produced a nonrandom sample and prevented the estimation of a survey response rate. These may affect the extent to which results can be extrapolated to represent the entire population of California growers.

4.3 Future Research

Vertebrate pest damage is a serious concern of agricultural producers and this study proved that the economic impacts of bird and rodent damage are not isolated to producers in the farm sector. Future research is needed to build upon the strengths and weakness of this study. Greater data collection of more multi-crop, multi-regional damage estimates is necessary to ensure control costs and pest damage estimates are representative of those incurred by all California producers. Further research is also needed at the household or retail level to gain a better understanding of the economic benefits that accrue to consumers. The higher wholesale prices in the absence of bird and rodent control would translate into higher retail prices at grocery stores throughout the US. These higher prices will disproportionally affect low income households who spend a larger budget share on food and may cause changes in consumption patterns. Dietary changes resulting from higher food costs could increase the occurrence of diseases stemming from poor nutrition and have the potential to significantly affect health care costs in the US. The benefits of bird and rodent control in California could be understated if these avoided health care costs are substantial.

Although this study measured the economic benefits of bird and rodent pest control in California and highlighted the fact that consumers nationwide benefit from California control, further policy analysis is needed to understand if the stringent regulations governing the use of bird and rodent pest controls in California are economically justified. As more reliable estimates of the economic benefits and costs associated with pesticide use become available, future analysis is needed to compare the costs and benefits associated with pest controls so that policy makers can better understand the true impacts of pesticide regulations.

Since California's Agriculture sector produces a commanding share of agricultural exports, changes in production within California have the potential to affect international markets. Future research is needed to explore how consumers and producers worldwide benefit from the yields protected by current control practices within the state, and to understand how pesticide regulation in California affects international trade. Although state regulations gives little consideration to individuals residing outside their borders, regulations negatively affecting one of the world's agricultural centers will certainly have widespread affects.

In addition to the future research needed to better understand bird and rodent pest damage, additional research examining the market structure of agricultural goods is needed. Any study examining changes in market supply or demand rely on elasticities. To provide more accurate estimates of hypothetical changes, supply and demand elasticities need to be updated to account for structural changes which have taken place over the past few decades.

REFERENCES

California Department of Food and Agriculture (CDFA), 2011. California Agricultural Resource Directory: 2011 - 2012. California Department of Food and Agriculture, Office of Public Affairs. Sacramento, CA

California Employment Development Department (CalEDD), 2011. Agricultural Employment in California. California Employment Development Department, Sacramento, CA. Accessed on May 22, 2012 < http://www.labormarketinfo.edd.ca.gov/>

California Environmental Protection Agency (CalEPA). 2010. State of California Agricultural Pest Control Advisor License Packet. Department of Pesticide Regulation, Pest Management and Licensing Branch. Sacramento, California.

California Environmental Protection Agency (CalEPA). 2010. State of California Qualified Applicator License Packet. Department of Pesticide Regulation, Pest Management and Licensing Branch. Sacramento, California.

California Environmental Protection Agency (CalEPA). 2010. State of California Qualified Applicator Certificate Packet. Department of Pesticide Regulation, Pest Management and Licensing Branch. Sacramento, California.

California Environmental Protection Agency (CalEPA). 2011. A Guide to Pesticide Regulation in California.California Department of Pesticide Regulation. Sacramento, California.

Carter, Colin A., James A. Chalfant, Rachel Goodhue, Kiara Grovess, and Leo K. Simon.2004. Impacts of Pesticide Regulation on the California Strawberry Industry. Selected Paper, American Agricultural Economics Association Annual Meeting, Denver, Colorado, August 1-4, 2004.

Carter, Colin A., Chalfant, James A., Goodhue, Rachael E., Han, Frank M., and Massimiliano DeSantis.2005. The Methyl Bromide Ban: Economic Impacts on the California Strawberry Industry.Review of Agricultural Economics. 2(2):181-197.

Clark, D.O., 1976. An overview of depredating bird damage control in California. Wildlife Damage Management, Internet Center for Bird Control Seminars Proceedings University of Nebraska – Lincoln, Year 1976.

Environmental Protection Agency (EPA-a). Updated February 3, 2012, What is a pesticide? epa.gov. Retrieved on February 09, 2011

Environmental Protection Agency (EPA-b). Updated January 10, 2012, Laws and Regulations.epa.gov. Retrieved on February 09, 2011

Esworthy, Robert. 2010. Pesticide Registration and Tolerance Fees: An Overview. Congressional Research Service. Washington D.C.

Environmental Protection Agency (EPA). 2011. Pesticides Industry Sales and Usage: 2006-2007 Market Estimates. Biological and Economic Analysis Division, Office of Pesticide Programs, Office of Chemical Safety and Pollution Prevention, U.S. Environmental Protection Agency. Washington, DC 20460

Hamilton, Lynn.2001.IPM in the Salad Bowl: Is it Cost Effective? Selected Paper session, American Agricultural Economics Association Meetings, Chicago, Ill., Aug. 5 - 8, 2001.

Hamilton, Lynn. 2007. Playing by the Rules: The High Cost of Regulation in California Agriculture. Presented at the International Agricultural Management Association Meeting, Parma, Italy June 23-26, 2007

Headley, J. C., 1968. Estimating the Productivity of Agricultural Pesticides. American Journal of Agricultural Economics 50, no. 1: 13-23.

Hurley, Sean, Richard Thompson, Christopher Dicus, Lori Berger and Jay Noel. 2006. Analysis of the Regulatory Effects on California Specialty Crops: An Examination of Various Issues Impacting Selected Forest Products, Tree Fruit, Nut and Vegetable Crop Industries.Available at: http://cissc.calpoly.edu

Johnson, R.J. and Timm, R.M., 1987. Wildlife Damage to Agriculture in Nebraska: A Preliminary Cost Assessment.Third Eastern Wildlife Damage Control Conference. Paper 29.

Johnston, Warren E. and Alex F. McCalla. “Wither California Agriculture: Up, Down or Out: Some Thoughts About the Future.” University of California Giannini Foundation Special Report 04-1, August 2004.

Kreith, Marcia, 2007. Wild Pigs in California: The Issues. Agricultural Issues Center, University of California Davis, AIC Issues Brief No. 33

Lee, Hyunok. California Horticulture: Current Trade and Policy Issues. Agricultural and Resource Economics Update 6(2):3-6.

Loomis, John B., and Richard G. and Walsh. Recreation Economic Decisions: Comparing Benefits and Costs. State College: Venture Publishing Inc., 1997.

Marsh, R., 1998. Historical review of ground squirrel crop damage in California. International Biodeterioration and Biodegradation, 42:93-99

McMillen, Stanley., 2006. The Economic Impact of the Arts, Film, History and Tourism Industries in Connecticut. Commissioned by the Connecticut on Culture and Tourism.

MKF Research LLC. 2005. Economic Impact of Wine and Vineyards in Napa County.

National Agricultural Statistics Service (NASS), 2002. U.S. Wildlife Damage. Agricultural Statistics Board, U.S. Department of Agriculture, 2pp.

Pimentel, D., H. Acquay, M. Biltonen, P. Ric, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz, and M. D'Amore.1992. Environmental and Economic Costs of Pesticide Use. Bioscience 42: 750-760.

Richardson, Harry W. Input-Output and Regional Economics. New York: John Wiley, 1972.

Rickman, Dan S., and R. Keith Schwer. "A Comparison of the multipliers of IMPLAN, REMI, and RIMS II: Benchmarking ready-made models for comparison." The Annals of Regional Science, 1995: 363-374.

Salmon, T.P., Crabb, A.C., Marsh, R., 1986. Bird Damage to Pistachios. California Agriculture 40(5):5-8

Sexton, S.E., Lei Z., Zilberman D., 2007. The Economics of Pesticides and Pest Control. International Review of Environmental and Resource Economics. 1, 271-326

Shwiff, Stephanie A., Gebhardt, Karen, Kirkpatrick, Katy N., 2009. The Economic Impact of Bird and Rodent Damage to California Crops: An economic evaluation of the losses caused by bird and rodent damage and selected benefits of pest control expenditures. USDA APHIS WS, National Wildlife Research Center, Fort Collins, Colorado

Stynes, Daniel. Economic impacts of Tourism: A handbook for tourism professionals. Urbana: University of Illinois, Tourism Research Laboratory. , 1997.

Toth, S. J., Jr. 1996. Federal Pesticide Laws and Regulations. Southern Region Pesticide Impact Assessment Program Fact Sheet. 4 pp.

Varian, H. 2009. Intermediate Microeconomics: A Modern Approach. 8th edn. New York, N.Y. W.W Norton & Company, Inc

Wade, Dale A.,1985. Pesticide Registration in the United States. Great PlainsWildlife Damage Control Workshop Proceedings. Paper 168.

APPENDIX A:

VERTEBRATE PEST DAMAGE SURVEY TOOL

Vertebrate Pest Damage Survey

Vertebrate pest damage can be a serious problem for growers in California. Many of the tools that were used to prevent damage in previous decades are no longer allowed, and some current options are under continuous threat of being banned. In part, this is because the general public and policymakers don't fully understand the benefits of controlling vertebrate pests. While the perception may be that control only benefits growers' bottom line, the truth is that the benefits are much more extensive. Effective pest control means consumers spend less money on the food they buy. A better bottom line for growers and more money in consumers' pockets ultimately means a healthier California economy with more jobs.

The California Department of Food and Agriculture in cooperation with the USDA-APHIS National Wildlife Research Center, is conducting a vertebrate pest damage survey to address these issues. The information you provide will allow the measurement of the benefits of vertebrate pest control in California, and will help ensure that a variety of pest control tools remain available to you. The objective of the study is to estimate the benefits of controlling birds, rodents, and feral hogs in California agriculture (excluding livestock and dairy). As many agriculture professionals are aware, there has been a gradual restriction in ability of growers to use methods that would control many of these agricultural pests, in part because policymakers and the public lack a complete understanding of the benefits of control and the extent of the damage. To address this, we will examine the benefit of controlling these pests in terms of the impact on grower revenue and income, and on other regional economic performance indicators.

The survey provides the key data for this study. Specifically, it will tell us:

- what the current level of damage is,
- what type of pest control methods are being used,
- how effective these methods are / what damage would be if there was no control.

The survey will be provided online through Survey Monkey and roughly takes five minutes to complete. It is anonymous and no personal information is collected, although respondents do have the option of entering their email address if they would like to have the results of the study sent to them.

CDFA has recently acquired a state-of-the-art regional economic modeling software program called REMI that will allow us to estimate how control of birds, rodents, and feral hogs benefits the California economy in terms of employment and output.

The key benefits of pest control that will be reported are:

- higher grower revenue and income,
- lower commodity prices,

- higher employment and output throughout the California economy.

The survey is designed to collect data on as many different crops as possible, and results will be reported separately for each crop and for each type of pest. Results of the survey and the economic study will be presented in a detailed report, USDA factsheets, press releases, and a manuscript published in a scientific journal. These materials will be made available to the survey collaborators and participants when completed.

To complete the survey, please visit https://www.surveymonkey.com/s/crop_2.

CA Crop Damage

Damage to California Crops

This short 15 minute questionnaire was developed to collect data about bird, rodent and feral hog damage to crops in California. Currently, data surrounding the amount and severity of this type of damage is limited. This questionnaire will ask you about your experience surrounding your top two most valuable crops. Your assistance in providing this information is greatly appreciated.

All respondents will remain anonymous.

This survey will be open from September 1-30, 2011.

CA Crop Damage

Demographics

How many years have you been farming?

What is your age?

Page 2

CA Crop Damage

Crop #1

***In a typical year, what is your MOST valuable crop?**

In what zip code does the majority of your production of this crop occur?

ZIP:

How many years have you been involved in the production of this crop?

***How many acres of this crop do you harvest in a typical year:**

Acres

In a typical year, what methods do you use to control each type of animal damage to this crop (indicate all that apply)?

	Birds	Rodents	Feral Hogs
Toxicants/poison	☐	☐	☐
Traps	☐	☐	☐
Non-lethal hazing	☐	☐	☐
Shooting	☐	☐	☐
Netting	☐	☐	☐
N/A	☐	☐	☐

What specie (ie. crow, pigeon, ground squirrel, etc.) do you believe causes the majority of damage to this crop?

Birds

Rodents

***In a typical year, how much do you spend total (all acres) to protect this crop?**

Birds

Rodents

Feral Hogs

***On what percentage of your acreage of this crop do you typically engage in pest control?**

Birds

Rodents

Feral Hogs

CA Crop Damage

***In a typical year, what percentage of your production of this crop is lost to pests?**

Birds

Rodents

Feral Hogs

***If you made NO attempt to control these pests (but other producers maintained current practices), what percentage of your production of this crop would be lost to pests?**

Birds

Rodents

Feral Hogs

***If all producers were prohibited from using any type of pest control, what percentage of your production of this crop do you think would be lost to pests?**

Birds

Rodents

Feral Hogs

CA Crop Damage

Do you produce more than one type of crop?

- ◯ Yes
- ◯ No

CA Crop Damage

Crop #2

In a typical year, what is your SECOND MOST valuable crop?

In what zip code does the majority of your production of this crop occur?

ZIP:

How many years have you been involved in the production of this crop?

How many acres of this crop do you harvest in a typical year:

Acres

In a typical year, what methods do you use to control each type of animal damage to this crop (indicate all that apply)?

	Birds	Rodents	Feral Hogs
Toxicants/poison	☐	☐	☐
Traps	☐	☐	☐
Non-lethal hazing	☐	☐	☐
Shooting	☐	☐	☐
Netting	☐	☐	☐
N/A	☐	☐	☐

What specie (ie. crow, pigeon, ground squirrel, etc.) do you believe causes the majority of damage to this crop?

Birds

Rodents

In a typical year, how much do you spend total (all acres) to protect this crop?

Birds

Rodents

Feral Hogs

On what percentage of your acreage of this crop do you typically engage in pest control?

Birds

Rodents

Feral Hogs

CA Crop Damage

***In a typical year, what percentage of your production of this crop is lost to pests?**

Birds

Rodents

Feral Hogs

If you made NO attempt to control these pests (but other producers maintained current practices), what percentage of your production of this crop would be lost to pests?

Birds

Rodents

Feral Hogs

If all producers were prohibited from using any type of pest control, what percentage of your production of this crop do you think would be lost to pests?

Birds

Rodents

Feral Hogs

CA Crop Damage

Thank-you for completing this survey!

APPENDIX B:

COMPARISON OF REGIONAL ECONOMIC MODELS

Characteristics	REMI	RIMS II	IMPLAN
I. Type	Conjoined input-output and behavior model	Regional input-output	Regional input-output
II. General Model Characteristics			
Year $'s can be entered	2005, 2010, or Nominal	N/A	depends on data set used
Reference Model	National A Matrix	National A Matrix	National A Matrix
Open/closed	Open	Both	Both
Time Invariant/ Variant	Dynamic	Static	Static
III. Sector Scheme			
Disaggregated	493	528	528
Aggregated	23 (county), 70 or 169 (state)	39	User choice
IV. Regionalization Technique			
Product Mix	Keep at disaggregated level	Keep at disaggregated level	Keep at disaggregated level
Consumption	BLS regional Consumer Expenditure Surveys	Row adjusted for commuting, column adjusted for savings and state tax leakages	Adjusted using RPC
Trade Patterns	Regional purchase coefficients	Regional purchase coefficients	Regional purchase coefficients
V. Impacts Measured			
Output	Yes	Yes	Yes
Employment	Yes	Yes	Yes
Income	Yes	Yes	Yes

Value-added	Yes	Yes	Yes
VI. Type of Multipliers			
Type I	Yes	Yes	Yes
Type II	Yes	Yes	Yes
Type SAM	Yes	NO	Yes
***note: REMI multipliers can be calculated from model output, but they have little meaning			
VII. Assumptions			
	• Utility and profit maximization • Cobb Douglas Production function with fixed proportion inputs • Homogeneous Output	• Linear Production function with constant return to scale • No constraints on supply • Price changes do not impact buying decisions • Homogeneous Output • Industries use the same technology to produce all outputs	• Linear Production function with constant return to scale • No constraints on supply • Price changes do not impact buying decisions • Homogeneous Output • Industries use the same technology to produce all outputs
VIII. Special Features			
	Incorporates Economic Geography, estimates migration changes, has specialized models to transportation and environmental issues		County and Zip Code level data
IV. Computer Requirement			

	IBM PC or Mainframe accessible via modem	IBM PC	IBM PC or Mainframe accessible via modem
V. Cost to Purchase Model			
	Variable depending on model specifications, offers leasing options. Range between $50,000- $90,000 for State level model	$275 Per Region $50 Per Industry –State Level	$350- Individual County $730- Individual County + Zip Codes $640- US or State Totals Multi Region Packages: $13,850- $72,500
Pros			
	• Incorporates relative prices • Can be used for forecasting and long-run analysis • Customized Simulation Available • Can analyze both supply and demand side factors	• Multipliers can be estimated for any county of group of counties • Relatively low cost • Multipliers are updated to reflect the most recent local area income data	• User friendly interface • Easy to adjust model specifications by omitting or adding variables • Relatively easy to change impact area
Cons			
	• Requires an extensive amount of data • Very costly to obtain the model • Model specifications cannot be easily modified	• Only applicable for short-run analysis • Limited to demand side shocks to final demands • Cannot be used for Multi-regional analysis	• Only applicable for short-run analysis • Limited to demand side shocks to final demands
Web Site	http://www.remi.com/	http://www.bea.doc.gov/bea/regional/rims	http://www.mig-inc.com/

Sources: "Analyzing the Economic Impact of Transportation Projects Using RIMS II, IMPLAN AND REMI" (Lynch 2000) IMPLAN 2010 Price Sheet

APPENDIX C: SURVEY RESULTS

Table C1: Survey Responses for Bird Damage

Crop	Responses	Average Acreage	Current Yield Loss	Yield Loss Without Control	Yield Savings	Per Acre Property Damage	Per Acre Property Damage Without Control
Alfalfa	19	356.12	5.29%	9.08%	3.99%	$ 1.61	$ 1.61
Almonds	49	373.08	2.14%	8.37%	5.75%	$ 5.61	$ 12.28
Apples	9	57.25	9.33%	35.00%	25.69%	$ 0.44	$ 178.03
Apricots	1	1.00	25.00%	60.00%	35.09%	$ 50.00	$ 50.00
Avocados	83	63.14	1.00%	2.70%	1.74%	$ 1.00	$ 7.50
Barley	2	250.00	2.25%	7.50%	5.25%	$ -	$ -
Blackberries	3	5.33	16.83%	51.67%	34.90%	$ 26.56	$ 774.72
Blueberries	1	1.00	30.00%	60.00%	30.09%	$ 1,500.00	---
Broccoli	1	400.00	0.00%	0.00%	0.00%	$ -	$ -
Brussel Sprouts	1	350.00	0.05%	0.05%	0.00%	$ -	$ -
Cabbage	1	200.00	0.50%	0.50%	0.00%	$ -	$ -
Carrots	1	225.00	1.00%	2.50%	1.51%	$ 2.22	$ 2.22
Cherimoyas	1	3.50	---	---	---	---	---
Cherries	9	84.67	6.56%	22.22%	16.49%	$ 2.80	$ 99.77
Citrus	54	204.49	0.97%	3.02%	2.07%	$ 0.20	$ 0.22
Cut Flowers	12	171.05	< 0.01%	3.41%	3.40%	$ 4.34	$ 6.28
Corn	7	168.36	7.14%	27.38%	20.25%	$ 2.24	$ 17.09
Dates	2	487.50	2.00%	27.00%	25.01%	$ -	$ -
Dry Beans	1	110.00	0.00%	0.00%	0.00%	$ -	$ -
Figs	1	8.00	45.00%	95.00%	50.23%	$ -	$ -

Grapes- Raisin	11	327.73	4.54%	19.44%	15.61%	$ 22.79	$ 323.94
Grapes-Table	14	266.83	7.18%	22.25%	16.23%	$ 225.43	$ 1,409.61
Grapes- Wine	84	241.28	6.30%	33.10%	32.75%	$ 4.60	$ 119.90
Green Beans	1	600.00	---	---	---	---	---
Hay	23	214.86	3.63%	10.71%	7.09%	$ 0.46	$ 7.07
Kiwi	2	20.00	---	---	---	---	---
Lettuce	11	2006.00	2.05%	15.47%	13.70%	$ 3.64	$ 13.99
Macadamia Nuts	2	2.00	0.38%	0.38%	0.00%	$ -	$ -
Melons	4	1376.25	1.17%	6.50%	6.49%	$ 6.44	---
Nursery Goods	18	52.21	0.62%	5.37%	4.75%	$ 8.81	$ 29.58
Olives	12	59.18	5.67%	11.33%	5.67%	$ 1.08	$ 1.29
Onions	2	52.50	7.50%	33.75%	26.27%	$ -	$ -
Pasture	25	1174.54	3.57%	82.47%	78.93%	$ 0.10	$ 3.43
Peaches	4	119.33	12.75%	42.50%	34.09%	$ 2.51	$ 89.39
Pears	6	24.60	2.75%	13.33%	10.58%	$ 3.27	$ 7.17
Peas	2	60.00	3.75%	---	---	---	---
Pecans	3	19.33	15.00%	32.50%	17.53%	$ -	$ -
Peppers	2	1005.00	1.25%	11.00%	9.75%	$ -	$ -
Persimmons	4	7.00	10.21%	14.50%	4.30%	$ -	$ -
Pistachios	7	1005.00	4.07%	16.48%	12.88%	$ 2.89	$ 7.19
Plums	4	104.00	3.94%	18.94%	15.01%	$ 101.84	$ 305.52
Pomegranates	3	153.33	5.00%	8.33%	3.33%	$ 0.08	$ 0.27
Potatoes	2	18.50	---	---	---	$ 11.65	$ 23.31
Prunes	6	320.67	2.25%	14.58%	12.34%	$ 2.71	$ 8.44
Rice	10	739.00	2.01%	12.21%	10.41%	$ 2.11	$ 17.81
Safflower	2	250.00	0.50%	1.50%	1.00%	$ -	$ -

Spinach	1	250.00	10.00%	50.00%	44.44%	$ 4.00	$ 4.00
Squash	4	126.75	2.92%	46.88%	43.97%	$ 13.26	$ 53.06
Strawberries	3	302.67	5.83%	18.33%	13.27%	$ 148.68	$ 242.29
Tomatoes-Fresh	4	6.63	3.35%	10.20%	7.09%	$ 38.48	$ 406.65
Tomatoes-Proc	8	362.71	2.63%	16.88%	14.63%	$ 4.58	$ 79.92
Walnuts	31	217.55	4.79%	11.42%	6.96%	$ 10.43	$ 20.61
Wheat	5	487.50	11.20%	17.33%	6.14%	$ 1.54	---

Table C2: Survey Responses Bird Control

Crop	Sound Devices	Visual Scare Devices	Land Mgmt	Promotion of Predators	Fencing/ Tree Guards	Netting	Chemical Repellant	Toxicants	Trapping	Shooting	Nothing	Other
Alfalfa	5%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	0%
Almonds	45%	29%	4%	8%	0%	4%	0%	0%	0%	41%	0%	0%
Apples	11%	44%	0%	0%	11%	22%	11%	0%	0%	11%	0%	11%
Apricots	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%
Avocados	2%	6%	0%	2%	1%	8%	0%	0%	0%	5%	18%	0%
Barley	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Blackberries	33%	100%	0%	0%	0%	33%	0%	0%	0%	33%	0%	0%
Blueberries	100%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	0%
Broccoli	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Brussel Sprouts	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Cabbage	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Carrots	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Cherimoyas	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Cherries	56%	22%	0%	22%	11%	0%	11%	11%	11%	44%	11%	0%
Citrus	4%	11%	0%	4%	2%	4%	2%	2%	0%	2%	11%	0%
Cut Flowers	0%	25%	0%	0%	0%	33%	0%	0%	0%	8%	8%	0%
Corn	29%	29%	26%	14%	0%	0%	0%	0%	0%	14%	43%	0%

Dates	0%	100%	100%	50%	50%	50%	0%	0%	0%	0%	0%	50%
Dry Beans	0%	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Figs	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grapes- Raisin	45%	45%	0%	36%	0%	18%	0%	0%	0%	27%	0%	0%
Grapes-Table	57%	50%	7%	29%	0%	14%	7%	0%	29%	57%	0%	0%
Grapes- Wine	36%	49%	11%	24%	1%	46%	1%	0%	1%	21%	8%	4%
Green Beans	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Hay	0%	4%	4%	0%	0%	4%	0%	9%	0%	13%	9%	0%
Kiwi	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Lettuce	36%	82%	36%	36%	9%	0%	0%	9%	9%	45%	0%	18%
Macadamia Nuts	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%
Melons	75%	75%	0%	0%	0%	25%	25%	0%	0%	0%	0%	25%
Nursery Goods	0%	39%	0%	11%	0%	17%	0%	0%	0%	6%	6%	6%
Olives	0%	17%	0%	0%	8%	8%	8%	8%	0%	0%	17%	0%
Onions	50%	50%	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%
Pasture	4%	12%	8%	4%	0%	0%	0%	0%	0%	16%	16%	0%
Peaches	50%	25%	0%	50%	0%	25%	0%	0%	0%	50%	0%	0%
Pears	17%	33%	0%	17%	17%	17%	0%	0%	0%	17%	0%	0%
Peas	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Pecans	0%	33%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Peppers	100%	100%	100%	0%	0%	0%	0%	0%	50%	50%	0%	0%
Persimmons	25%	75%	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%
Pistachios	86%	71%	0%	14%	0%	14%	0%	14%	14%	71%	0%	0%
Plums	0%	25%	25%	0%	0%	25%	25%	0%	25%	25%	0%	0%
Pomegranates	0%	0%	0%	0%	0%	0%	33%	33%	0%	0%	0%	0%
Potatoes	50%	0%	50%	0%	0%	0%	0%	0%	0%	50%	0%	0%
Prunes	17%	33%	0%	0%	0%	17%	0%	0%	0%	17%	0%	0%
Rice	70%	40%	30%	0%	0%	0%	0%	0%	0%	40%	10%	0%
Safflower	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Spinach	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Squash	25%	0%	0%	0%	0%	0%	25%	0%	0%	25%	0%	0%
Strawberries	67%	100%	33%	33%	0%	67%	0%	0%	33%	0%	0%	0%
Tomatoes-Fresh	25%	50%	0%	50%	0%	0%	0%	0%	0%	25%	25%	0%
Tomatoes-Proc	25%	50%	0%	13%	0%	0%	0%	0%	0%	13%	0%	0%
Walnuts	17%	27%	10%	7%	0%	3%	0%	0%	0%	33%	13%	0%

Wheat	40%	20%	20%	20%	0%	0%	0%	0%	20%	40%	20%	0%

Table C3: Survey Responses for Rodent Damage

Crop	Responses	Average Acreage	Current Yield Loss	Yield Loss Without Control	Yield Savings	Per Acre Property Damage	Per Acre Property Damage Without Control
Alfalfa	19	356.12	7.75%	39.46%	34.52%	$ 19.24	$ 105.58
Almonds	49	373.08	2.73%	21.07%	18.86%	$ 11.78	$ 61.59
Apples	9	57.25	8.15%	46.04%	37.92%	$ 1.71	$ 2,202.17
Apricots	1	1.00	---	---	---	---	---
Avocados	83	63.14	4.90%	15.90%	9.63%	$ 20.30	$ 70.05
Barley	2	250.00	40.00%	70.00%	30.12%	$ 8.20	$ 12.60
Blackberries	3	5.33	11.70%	41.67%	30.01%	$ 106.25	$ 700.00
Blueberries	1	1.00	---	---	---	---	---
Broccoli	1	400.00	0.00%	0.00%	0.00%	$ -	$ -
Brussel Sprouts	1	350.00	0.50%	1.00%	0.50%	$ -	$ -
Cabbage	1	200.00	5.00%	50.00%	45.02%	$ -	
Carrots	1	225.00	2.00%	20.00%	18.36%	$ 22.22	$ 100.00
Cherimoyas	1	3.50	---	---	---	---	---
Cherries	9	84.67	4.33%	16.83%	13.06%	$ 12.43	$ 77.19
Citrus	54	204.49	3.24%	21.08%	18.44%	$ 74.91	$ 237.22
Cut Flowers	12	171.05	8.82%	12.14%	3.32%	$ 87.72	$ 261.59
Corn	7	168.36	3.32%	8.10%	4.78%	$ 10.98	$ 17.86
Dates	2	487.50	1.50%	9.00%	7.50%	$ -	$ 0.03
Dry Beans	1	110.00	0%	0%	0.00%	$ 12.50	$ 12.50
Figs	1	8.00	10.00%	30.00%	20.02%	$ 12.50	$ 12.50
Grapes- Raisin	11	327.73	2.67%	14.67%	12.33%	$ 18.16	$ 287.96

Grapes-Table	14	266.83	2.88%	13.76%	11.20%	$ 11.12	$ 709.95
Grapes- Wine	84	241.28	4.30%	18.40%	17.58%	$ 9.50	$ 42.40
Green Beans	1	600.00	---	---	---	---	---
Hay	23	214.86	12.69%	32.68%	20.02%	$ 8.91	$ 44.91
Kiwi	2	20.00	---	---	---	---	---
Lettuce	11	2006.00	1.72%	9.36%	7.77%	$ 2.63	$ 5.53
Macadamia Nuts	2	2.00	6.25%	18.75%	12.51%	$ 25.00	$ 68.75
Melons	4	1376.25	1.45%	11.67%	10.35%	$ 12.72	$ 29.08
Nursery Goods	18	52.206	1.86%	20.06%	18.20%	$ 75.01	$ 3,264.36
Olives	12	59.18	11.29%	23.65%	12.37%	$ 19.73	$ 1,608.56
Onions	2	52.50	2.75%	33.00%	30.26%	$ 19.05	$ 64.29
Pasture	25	1174.54	10.83%	32.09%	21.28%	$ 3.00	$ 8.50
Peaches	4	119.33	2.92%	23.33%	21.03%	$ 4.40	$ 18.43
Pears	6	24.60	4.17%	27.92%	23.76%	$ 87.35	$ 117.85
Peas	2	60.00	---	---	---	---	---
Pecans	3	19.33	5.17%	14.17%	9.00%	$ 31.60	$ 72.22
Peppers	2	1005.00	1.25%	21.00%	19.75%	$ -	$ -
Persimmons	4	7.00	19.13%	39.38%	20.29%	$ 11.61	$ 46.43
Pistachios	7	1005.00	2.89%	12.21%	9.60%	$ 4.48	$ 21.56
Plums	4	104	1.98%	5.83%	3.85%	$ 13.94	$ 55.49
Pomegranates	3	153.33	4.05%	36.67%	32.63%	$ 2.84	$ 12.15
Potatoes	2	18.5	3.75%	15.00%	11.25%	$ 23.31	$ 46.62
Prunes	6	320.667	5.21%	18.75%	13.55%	$ 15.59	$ 32.27
Rice	10	739	1.69%	4.86%	5.83%	$ 1.22	$ 2.31
Safflower	2	250	3.75%	22.50%	18.76%	$ 0.60	$ 1.80
Spinach	1	250	2.00%	2.00%	0.00%	$ 0.80	$ 1.20
Squash	4	126.75	15.00%	60.67%	45.74%	$ 99.21	$ 238.10
Strawberries	3	302.667	12.71%	27.08%	16.46%	$ 70.17	$ 187.12

Tomatoes-Fresh	4	6.625	4.50%	16.25%	12.30%	$ 183.02	$ 1,008.96
Tomatoes-Proc	8	362.714	9.19%	46.88%	41.51%	$ 16.35	$ 105.36
Walnuts	31	217.553	5.89%	25.19%	20.51%	$ 21.90	$ 88.12
Wheat	5	487.5	8.40%	15.00%	6.61%	$ 5.90	$ 13.33

Table C4: Survey Responses for Rodent Control

Crop	Sound Devices	Visual Scare Devices	Land Mgmt	Promotion of Predators	Fencing/ Tree Guards	Netting	Chemical Repellant	Toxicants	Trapping	Shooting	Nothing	Other
Alfalfa	0%	0%	63%	42%	0%	0%	5%	74%	53%	37%	0%	10%
Almonds	0%	2%	37%	33%	16%	2%	14%	88%	53%	63%	0%	0%
Apples	7%	2%	12%	29%	12%	4%	14%	70%	66%	34%	5%	0%
Apricots	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Avocados	0%	0%	11%	11%	0%	0%	0%	67%	33%	0%	0%	0%
Barley	7%	2%	26%	39%	13%	2%	11%	67%	56%	30%	2%	4%
Blackberries	9%	0%	27%	36%	18%	0%	18%	64%	55%	64%	9%	0%
Blueberries	7%	0%	26%	43%	14%	7%	14%	86%	50%	29%	7%	14%
Broccoli	0%	1%	38%	56%	15%	1%	13%	60%	55%	27%	5%	1%
Brussel Sprouts	0%	0%	64%	18%	27%	0%	9%	64%	45%	36%	0%	0%
Cabbage	50%	0%	0%	25%	50%	0%	25%	50%	0%	0%	0%	0%
Carrots	25%	0%	0%	0%	0%	0%	50%	75%	25%	0%	0%	0%
Cherimoyas	0%	0%	29%	57%	29%	0%	14%	71%	29%	43%	0%	14%
Cherries	10%	10%	40%	0%	10%	0%	10%	30%	20%	30%	0%	0%
Citrus	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Cut Flowers	0%	0%	33%	0%	67%	0%	33%	100%	100%	0%	0%	33%
Corn	50%	0%	0%	25%	0%	25%	0%	50%	75%	25%	25%	0%
Dates	25%	0%	25%	50%	0%	0%	13%	88%	25%	25%	0%	0%
Dry Beans	10%	7%	20%	23%	13%	3%	10%	73%	3%	6%	10%	7%
Figs	0%	0%	63%	42%	0%	0%	5%	74%	53%	37%	0%	10%
Grapes- Raisin	0%	2%	37%	33%	16%	2%	14%	88%	53%	63%	0%	0%
Grapes-Table	7%	2%	12%	29%	12%	4%	14%	70%	66%	34%	5%	0%

Grapes- Wine	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Green Beans	0%	0%	11%	11%	0%	0%	0%	67%	33%	0%	0%	0%
Hay	7%	2%	26%	39%	13%	2%	11%	67%	56%	30%	2%	4%
Kiwi	9%	0%	27%	36%	18%	0%	18%	64%	55%	64%	9%	0%
Lettuce	7%	0%	26%	43%	14%	7%	14%	86%	50%	29%	7%	14%
Macadamia Nuts	0%	1%	38%	56%	15%	1%	13%	60%	55%	27%	5%	1%
Melons	0%	0%	64%	18%	27%	0%	9%	64%	45%	36%	0%	0%
Nursery Goods	50%	0%	0%	25%	50%	0%	25%	50%	0%	0%	0%	0%
Olives	25%	0%	0%	0%	0%	0%	50%	75%	25%	0%	0%	0%
Onions	0%	0%	29%	57%	29%	0%	14%	71%	29%	43%	0%	14%
Pasture	10%	10%	40%	0%	10%	0%	10%	30%	20%	30%	0%	0%
Peaches	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Pears	0%	0%	33%	0%	67%	0%	33%	100%	100%	0%	0%	33%
Peas	50%	0%	0%	25%	0%	25%	0%	50%	75%	25%	25%	0%
Pecans	25%	0%	25%	50%	0%	0%	13%	88%	25%	25%	0%	0%
Peppers	10%	7%	20%	23%	13%	3%	10%	73%	3%	6%	10%	7%
Persimmons	0%	0%	63%	42%	0%	0%	5%	74%	53%	37%	0%	10%
Pistachios	0%	2%	37%	33%	16%	2%	14%	88%	53%	63%	0%	0%
Plums	7%	2%	12%	29%	12%	4%	14%	70%	66%	34%	5%	0%
Pomegranates	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Potatoes	0%	0%	11%	11%	0%	0%	0%	67%	33%	0%	0%	0%
Prunes	7%	2%	26%	39%	13%	2%	11%	67%	56%	30%	2%	4%
Rice	9%	0%	27%	36%	18%	0%	18%	64%	55%	64%	9%	0%
Safflower	7%	0%	26%	43%	14%	7%	14%	86%	50%	29%	7%	14%
Spinach	0%	1%	38%	56%	15%	1%	13%	60%	55%	27%	5%	1%
Squash	0%	0%	64%	18%	27%	0%	9%	64%	45%	36%	0%	0%
Strawberries	50%	0%	0%	25%	50%	0%	25%	50%	0%	0%	0%	0%
Tomatoes-Fresh	25%	0%	0%	0%	0%	0%	50%	75%	25%	0%	0%	0%
Tomatoes-Proc	0%	0%	29%	57%	29%	0%	14%	71%	29%	43%	0%	14%
Walnuts	10%	10%	40%	0%	10%	0%	10%	30%	20%	30%	0%	0%
Wheat	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%