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Economic Consequences of Mandated Grading and Food Safety Assurance: *Ex Ante* Analysis of the Federal Marketing Order for California Pistachios

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This publication has been anonymously peer-reviewed for technical accuracy by University of California scientists and other qualified professionals.

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

The U.S. pistachio industry, located almost exclusively in California, has experienced phenomenal growth over the past 30 years, both in absolute terms and as a share of the global pistachio industry, which has also grown rapidly. In recent years, a group of growers led an initiative to establish a federal marketing order that would mandate quality standards and an inspection program to assure consistency in the quality of California pistachios, thereby increasing consumer demand and confidence in the product, and enhance producer returns. Hearings sponsored by the U.S. Department of Agriculture (USDA) were held in 2002 and the marketing order will be established in August 2005.

The federal marketing order for California pistachios will be funded by revenues raised using assessments on each pound of pistachios processed for the domestic market. If the policy is effective as envisaged, benefits from demand enhancement will more than offset the cost of the assessments. In 2002, Sumner undertook an initial study to estimate the likely costs and benefits of the proposed program and presented testimony at public hearings in Fresno on July 23–25, 2002. We have extended that work to encompass a broader range of modeling approaches and assumptions and a much more comprehensive investigation of the supply and demand fundamentals. This report documents the industry situation, the issues to be addressed by the policy, the model, and results from the benefit-cost assessment. As well as being of specific interest in its own right, this analysis sets some useful precedents as the first *ex ante* quantitative analysis of a collective action program designed to enhance demand through quality assurance.

2. THE CALIFORNIA PISTACHIO INDUSTRY AND THE NEW MARKETING ORDER

The California pistachio industry has grown quickly and now occupies an important and growing share of the world market. Prior to discussing our model of the industry, it is useful to discuss trends in production and consumption, the issue of aflatoxin in pistachios, the economic rationale for a collective action program in the industry, and the specific features of the proposed marketing order.

2.1. Trends in Production and Consumption of Pistachios

World production of pistachios has grown rapidly during the past three decades and U.S. production has increased as a share of that growing total.[1] Iran is still the largest producer, but the United States is established as the second largest pistachio producer in the world, followed by Syria and Turkey, and is now the second largest exporter after Iran.[2] The United States also imports small amounts.[3] Figure 2.1 shows U.S. and world production over the years 1980–2003 and Appendix Table A1 provides details on national production patterns. As well as showing strong total and U.S. growth, Figure 2.1 shows substantial year-to-year swings in production, reflecting yield variability.

Almost all U.S. pistachios are produced in California.[4] The California pistachio industry has experienced phenomenal growth over the past 30 years. California's production has grown more than 200-fold since 1976, when the first commercial crop of 1.5 million pounds was harvested. California produced a record crop of 302 million pounds in 2002, up from the previous record of approximately 242 million pounds in 2000. The 2003 crop was smaller—118 million pounds. The longer-term trends have shown steadily increasing acreage, yields, quantities, and value of production and corresponding downward trends in prices with important fluctuations around those trends. We have also seen steady growth in California exports as a share of world trade and as a share of production.

Figure 2.2 shows California's nonbearing, bearing, and total acreage of pistachios over the years 1980–2003 based on data shown in Appendix Table A2. Total acres of pistachios in California have increased from 34,726 in 1980 to 111,000 in 2003. Normally, it takes a pistachio tree five or six years to mature before it produces an economically significant crop and twelve to fifteen years to reach full potential. Bearing acreage for 2003 was estimated by the California Agricultural Statistics Service (CASS) to be 86,000 acres, up 6 percent from 83,000 bearing acres in 2002 and 234 percent from 25,773 bearing acres in 1980. The growth in area and production has been very consistent for the past 23 years and is expected to continue; nonbearing acreage reached 23,000 acres in 2003 (CASS).

Annual production is variable and hard to predict. Like many other tree fruits and nuts, pistachio yields and production have an alternate bearing cycle. The trees generally have a high-yield year followed by a low-yield year, but there are exceptions, as can be seen

1 Statistical information in this section was supplied by the California Pistachio Commission (CPC) unless otherwise noted. Some information was provided as a personal communication and some was taken directly from the Web site *www.pistachios.org*.

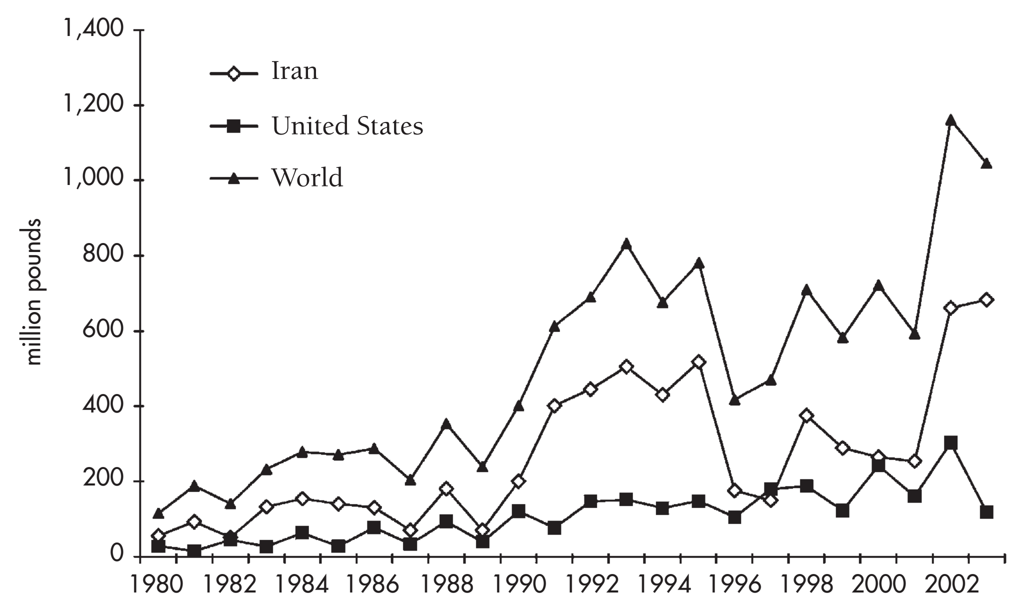
2 Iran's exports peaked in 1996, when it exported 308 million pounds of pistachios, but exports fell to 127 million pounds in 1997, the year Iranian pistachios were banned in the European Union because of high levels of aflatoxin. Iranian exports returned gradually to near pre-ban levels in the following few years.

3 Turkey is by far the largest exporter to the United States, accounting for 83 percent of all imported pistachios. Turkish pistachios are smaller than U.S. varieties and they also taste different. The total quantity of pistachios imported during the 2000–01 crop year was 1.8 million pounds or 0.8 percent of domestic production.

4 In 2000, Arizona produced 4 million pounds of pistachios on 2,700 acres, just 1.5 percent of national production that year (Arizona Agricultural Statistics Service). This share was too small to have a significant impact on the national market for pistachios. New Mexico had 391 acres of pistachios in 1999, less then half a percent of total acreage (New Mexico Agricultural Statistics Service).

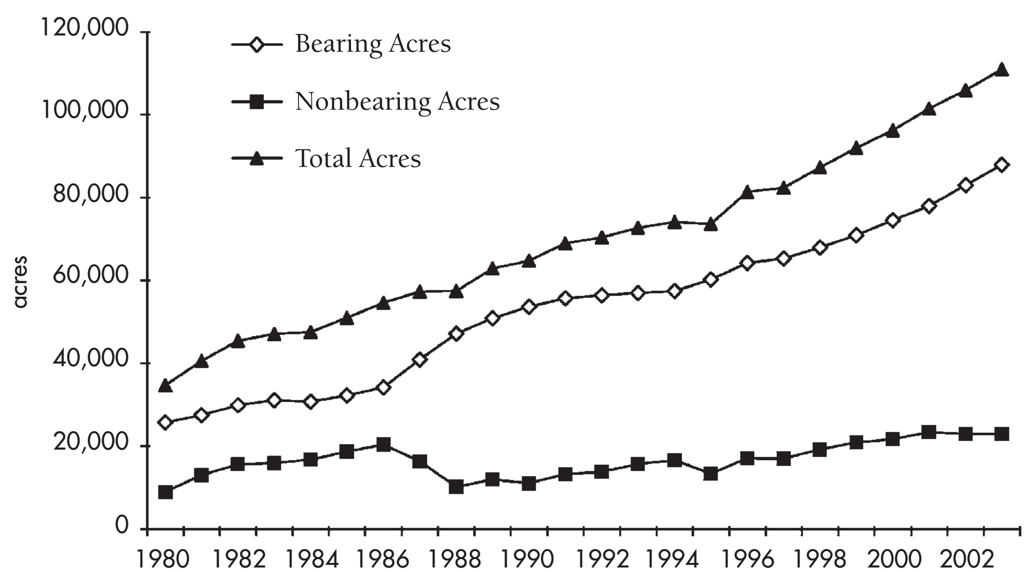
in Figure 2.3 (based on yield data shown in Appendix Table A2).[5] Other factors affect production and yields, including weather and new trees coming into production. The yield cycle is an important factor in quantity produced, price received, total value of the crop, and gross revenue per bearing acre (USDA Risk Management Agency (RMA)).

Figure 2.1. U.S. and World Production of Pistachios, 1980–2003



Source: Appendix Table A1.

Figure 2.2. Bearing, Nonbearing, and Total Acres of California Pistachios, 1980–2003



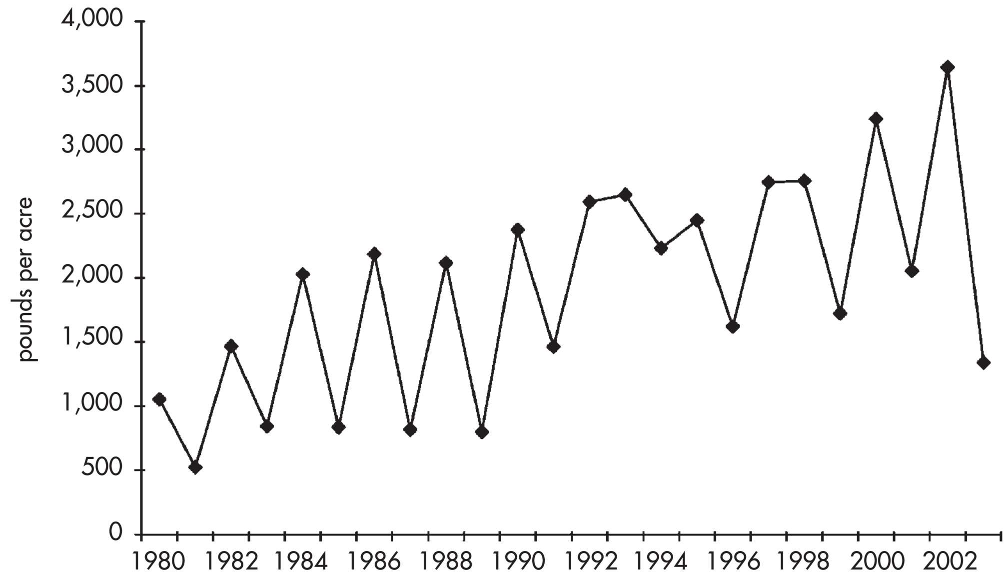
Source: Appendix Table A2.

[5] California pistachio yields were 1,055 pounds per acre in 1980 but fell to 523 pounds per acre in 1981. The yield rebounded in 1982 to 1,468 pounds per acre. The high-yield years 1992 and 1997 were both followed by even higher yields, breaking the alternate bearing pattern.

Pistachio quality also varies. A certain percentage of the nuts have not opened before they are harvested and are classified as "closed shell" or "shelling stock." These nuts do not have the same value as "open shell" nuts but can be sold to processors or exported. Often, the share of nuts that have not split is higher during high-yield years. In 2000, 78.2 percent of the high-yield crop was open-shell; the 1999 low-yield crop was 85.3 percent open-shell. However, the 2002 record crop was 79.9 percent open-shell compared to 75.6 percent for the lower-yield crop in 2003. Appendix Table A3 includes data on pistachio production and quantities and shares in the categories of closed-shell, shelling stock, and open-shell pistachios.

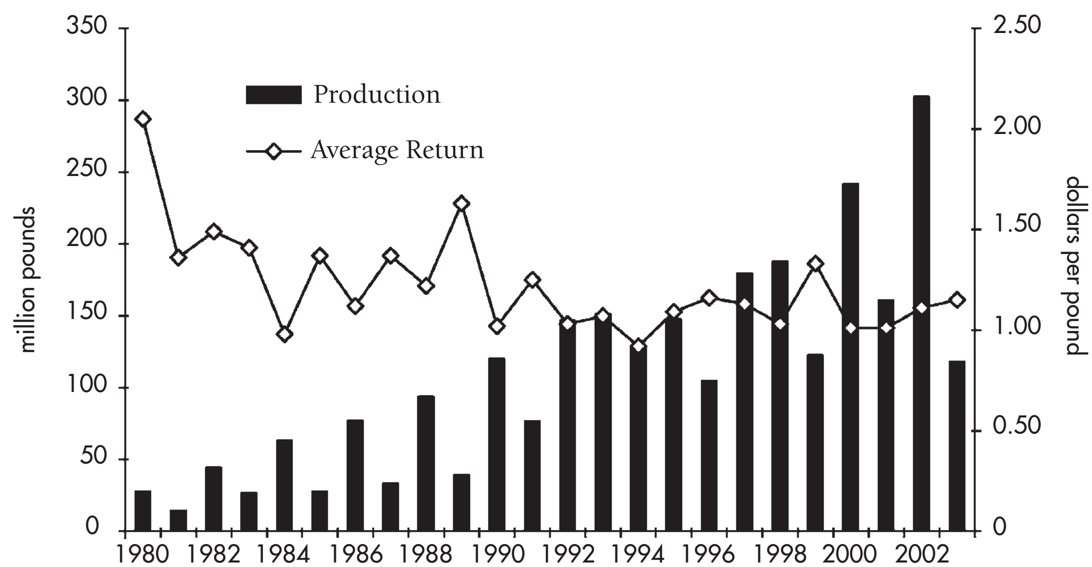
The value of the crop varies with the quantity produced. The long-term trend is for increasing

Figure 2.3. Yield per Bearing Acre of California Pistachios, 1980–2003



Source: Appendix Table A2.

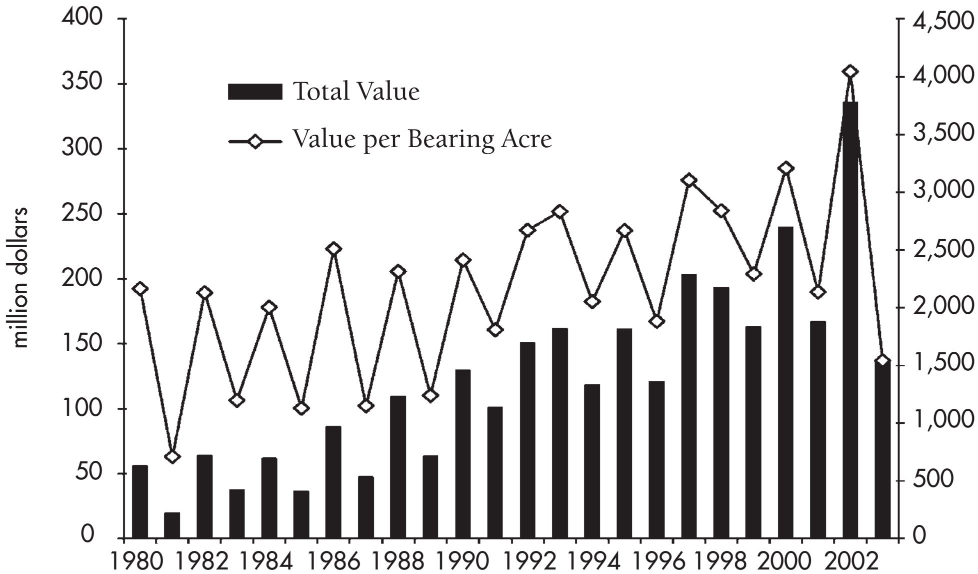
Figure 2.4. Total Quantity and Price per Pound for California Pistachios, 1980–2003



Source: Appendix Table A4.

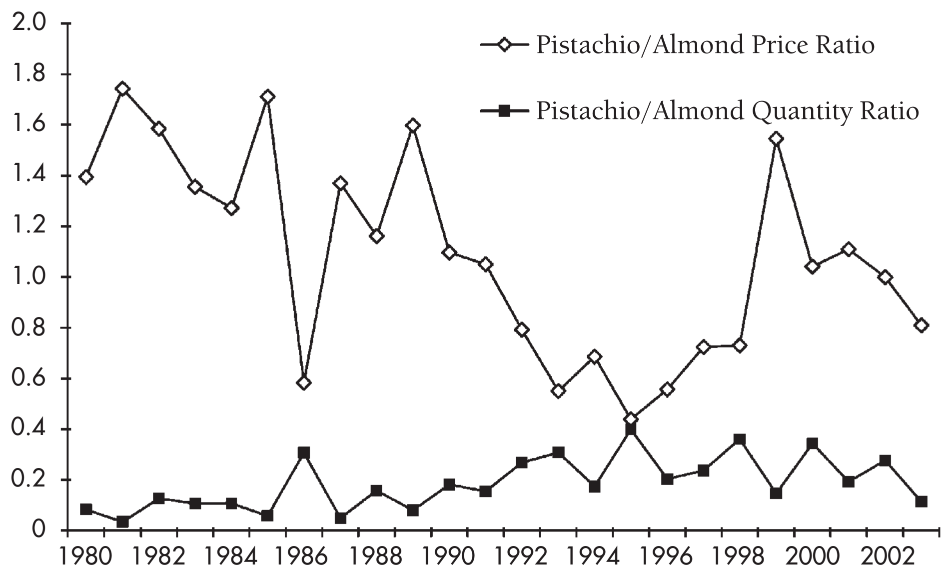
quantity and increasing value of the crop but falling returns per pound, which reflects the fact that supply has been growing faster than demand. The trend for the past 23 years in price per pound (even in nominal terms) has been gradually downward from the high in 1980 of $2.05 a pound to $1.15 per pound in 2003, as can be seen in Figure 2.4, which is based on data shown in Appendix Table A4.

Figure 2.5. **Total Value and Value per Bearing Acre of California Pistachios, 1980–2003**



Source: Appendix Table A4.

Figure 2.6. **Ratios of Price and Quantity for California Pistachios and Almonds, 1980–2003**



Source: Appendix Table A5.

Despite declining prices, total value and gross revenue per bearing acre have been trending up over the past 22 years. Total value has increased significantly, mostly from increases in total acreage but also partly from increases in yield per acre. In 1980, California's pistachio crop was valued at $55.8 million, only one-sixth of the value of the 2002 crop. Gross revenue per bearing acre has gone up in the past 22 years, partly because California's trees have been maturing and consequently producing higher yields. The five-year average of gross revenue per bearing acre was $1,642 during 1980–1984, compared with $2,904 per acre during 1998–2002. Figure 2.5, which is based on data shown in Appendix Table A4, shows the trends in total value of production and gross value of production per bearing acre.

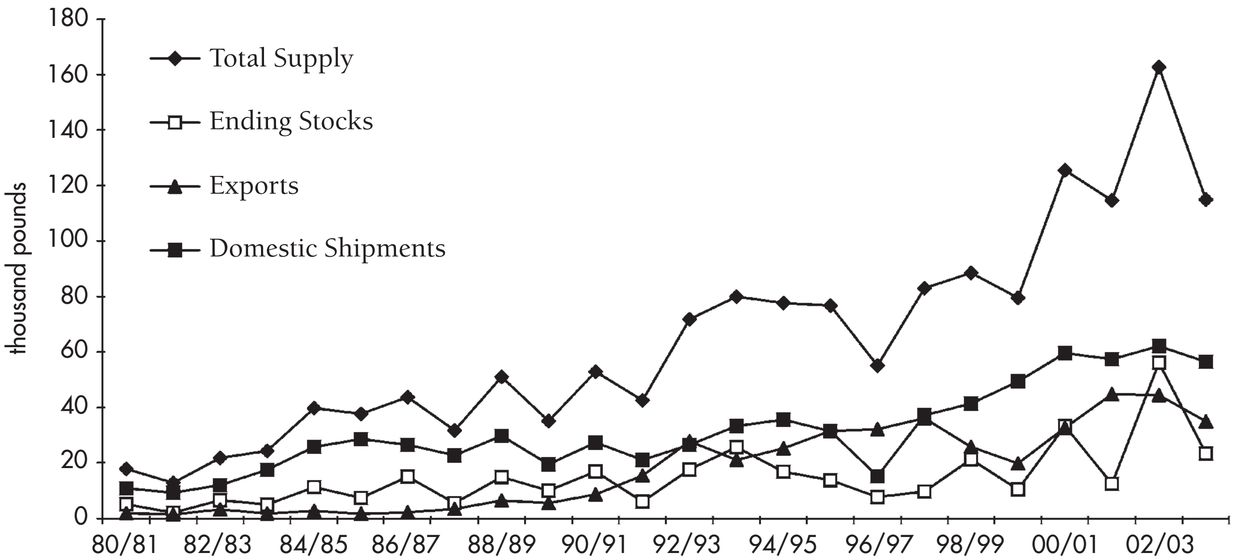
The alternate-bearing nature of pistachio trees plays a key role in the value of the crop. Production can change significantly from one year to the next as a result of large changes in yield, but this can be mitigated by adjustments in reserve stocks. Price varies inversely with volume and California production is important enough to influence the world price, but part of the story is that California's large-crop years have often coincided with large crops globally. With the exception of 2002, the total value and the value per acre in large-crop years have generally been higher in more recent years even though prices have been lower. Hence, the bumper pistachio crop in 2000 produced the second-highest crop value on record. The 241 million pounds of pistachios produced that year had a total value of $239 million, or $3,207 per bearing acre. The average return per pound of $0.99 in 2000 was the lowest since 1984. However in 2002, the price was up to $1.11 per pound despite the 302 million pounds produced that year, which had a crop value of more than $335 million, or $4,044 per bearing acre.

Along with changes in the quantity and value of production, we have witnessed trends and year-to-year variation in allocation of the crop between domestic and export markets. Domestic consumption of pistachios increased from 10.9 million pounds in 1980–81 to 56.5 million pounds in 2003–04, reflecting both an increase in population and an increase in per capita consumption from 0.05 to 0.22 pounds per person per year. The growth in per capita consumption reflects several factors, including lower real prices of pistachios compared with foods generally and compared with other nuts in particular, higher real incomes and income-responsive demand, and perhaps shifts of dietary patterns toward foods that are healthier, natural, and more convenient. Figure 2.6, which is based on the data shown in Appendix Table A5, compares trends in production and farm prices for pistachios and almonds in California.

Export sales have grown even more rapidly, reflecting the same forces at work in other consuming countries combined with faster growth in U.S. production compared with other exporters. The United States exported almost 41 million pounds of pistachios in the 2002–03 crop year. Major export destinations in 2003 were the European Union (EU) (Belgium, Germany, Italy, France, The Netherlands, and Luxembourg), which accounted for more than half of the total value of exports, and Canada, China, and Japan. The value of U.S. pistachio exports rose steadily until 1999, when it decreased from more than $120 million to less than $90 million (U.S. International Trade Commission). Since then, export values and volumes have been greater. The value of U.S. pistachio exports reached $135 million in 2003. Figure 2.7, which is based on the data shown in Appendix Table A6, shows the trends in allocation of U.S. production between domestic and export markets and changes in stocks.

In 2002, California had approximately 650 pistachio producers (USDA, Agricultural Marketing Service (AMS) 2003b). There was a single pistachio-producer cooperative and 19 handlers that processed pistachios. About 70 percent of California pistachio producers produce less than 100,000 pounds per year, 21 percent produce more than 100,000 and less than 500,000 pounds, and about 9 percent produce more than 500,000 pounds. Using an average grower price of $1.10 per pound, this means that about 91 percent of California's pistachio producers generate less than $550,000 in annual revenue and 9 percent generate more than $550,000 annually. About 85 percent of California pistachio handlers handle less than ten million pounds per year and about 15 percent handle more than ten million pounds annually. The largest handler processes about 50 percent of the industry's production.

Figure 2.7. **Allocation of California Pistachios among Markets for 1980/81–2003/04 (Preliminary for Final Year)**



Source: Appendix Table A6.

2.2. Collective Action by Growers to Support Pistachio Markets

Many California crops have instituted collective action programs that are supported by federal or state legislation. These programs are industry-initiated, self-financed, and government-mandated. Lee et al. documented and described the different forms of mandated marketing programs in California and their legal basis, as well as the amounts spent under each program and the allocations of funds to research, promotion, and other activities. They reported that in May 1995 there were 48 state marketing programs (including marketing orders, commissions, and councils) and 13 federal marketing orders in effect in California covering about half of California's agricultural production and spending more than $100 million per year. Since then, there have been some changes in programs and total spending has grown, exceeding $170 million in 2002–03 (Carman and Alston).

State marketing orders are authorized by the California Marketing Act of 1937, whereas each commodity commission and council is authorized by a specific piece of legislation. Each administrative body is authorized to collect assessments from producers and in some cases from handlers based on the number of units or the value of the commodity at the first-handler level. These assessments are used to fund authorized activities that can include quantity controls, market promotion, research and development, container and pack regulations, and quality standards and inspection. The majority of California's state marketing programs are for fruits, nuts, and vegetables and in most, but not all, cases the lion's share of their expenditures goes to promotion.

Federal marketing orders are authorized by the Agricultural Marketing Agreement Act of 1937. They are similar to state marketing orders and the enabling legislation was enacted at the same time, but there are some differences. Federal marketing orders can cover a production region in more than one state while state marketing programs are restricted to commodities produced in individual states. Federal marketing orders tend to focus on quality regulations and sometimes on volume controls while state programs tend to focus more on research and promotion. Federal marketing orders are applicable to milk and specified groups of fruit, vegetables, and other specialty crops while state marketing programs are available for all commodities. Federal marketing orders that set standards for quality and related requirements are in place for many California fruits and vegetables. In addition, USDA provides testing and grading services for many commodity markets (USDA, AMS 2003a).

The California Pistachio Commission

California pistachio growers formed the California Pistachio Commission (CPC) in 1981 to provide support through public relations, government relations, marketing, and production research funded by an assessment of $0.035 per pound of pistachios produced in California.[6] Since its inception, CPC has sponsored research on a wide variety of cultural challenges such as disease and insect control, methods of increasing production yields, and cultivar improvement. CPC also publishes a quarterly industry newsletter, *The Pistachio Perspective*, which contains the latest industry-related information and articles on control of pests and diseases, industry events, the commission's domestic and export promotion programs, and legislative issues affecting the industry.

Through USDA's Foreign Agricultural Service (FAS), CPC receives funding under the Market Access Program (MAP) to promote California pistachio exports in Japan, Korea, China, Malaysia, the Philippines, Thailand, Canada, and the United Kingdom. MAP funds to the pistachio industry averaged about $800,000 per year during the five years ending in 2002 (USDA, FAS 2003b). CPC also supports a number of additional export markets through commission-funded programs. In 2002–03, CPC spent a total of almost $9 million, more than $6 million of which was for promotion (Carman and Alston).

The Federal Marketing Order for California Pistachios

In July 2002, hearings were held in Fresno on a proposal to establish a federal marketing order for pistachios grown in California. The proposed order was recommended by USDA's Agricultural Marketing Service and put out for comment and a grower vote in early 2004. The proposal was supported by 90 percent of the growers voting and the marketing order is expected to be established in August 2005. Table 2.1 documents key events in the history of the establishment of the order.

The stated objective of the program is to enhance grower returns through delivery of higher-quality pistachios to consumers.[7] Hitherto, industry quality-control practices were limited to voluntary testing for aflatoxin and other quality requirements under a marketing agreement for California pistachios that was entered into by a number of pistachio handlers under authority of the California Department of Food and Agriculture (CDFA). That agreement was limited to issues relating to blending artificially opened pistachios with those that opened naturally and to bleaching of pistachios. Under the agreement, aflatoxin testing and sampling guidelines were used only for exports to specified countries.

The proposed federal marketing order sets standards for the quality of pistachios produced and handled in California by establishing a maximum aflatoxin tolerance level, maximum limits for defects, a minimum size requirement, and mandatory inspection and certification. These standards apply solely to pistachios marketed in the United States. An eleven-member committee consisting of eight producers, two handlers, and one public member will administer the program. The program will be financed by assessments on handlers of pistachios grown in the production area.

Aflatoxin is the main issue behind the marketing order, which states that no handler shall ship for domestic human consumption pistachios that exceed an aflatoxin level of 15 parts per billion (ppb).[8] An aflatoxin inspection certificate must cover all domestic pistachio shipments. The marketing order further outlines aflatoxin-testing procedures that must be completed to obtain the aflatoxin inspection

[6] Details on CPC's history and activities can be found on its Web site, *www.pistachios.org*.

[7] Details here are based on the proposed rule (USDA, AMS 2003a, pp. 45990–46033).

[8] This is a tighter standard than the current maximum allowed by the U.S. Food and Drug Administration of 20 ppb.

Table 2.1. **History of the Federal Marketing Order for California Pistachios**

Date	Event
1996	The California Pistachio Commission and Western Pistachio Association attempted to establish a federal marketing order. The attempt was terminated in 2000 due to lack of industry support for certain provisions.
2000	The Proponents Committee for the federal marketing order was established as a consequence of renewed interest in such an order.
2001–2002	The Proponents Committee developed a proposal that aimed to achieve an industry consensus and gather evidence to meet USDA criteria.
July 23–25, 2002	A public hearing was held in Fresno, California, by USDA to receive evidence on the proposed marketing order from producers, handlers, and other interested parties.
December 11, 2003	An affirmative decision was declared by the U.S. Secretary of Agriculture and a referendum order was issued.
Jan. 12–Feb. 9, 2004	The referendum was conducted among California growers.
March 1, 2004	The referendum results were published. The marketing order was favored by voters representing 90 percent of the total volume of production voted in the referendum.
April 4, 2004	The final rule establishing a marketing order for pistachios grown in California to begin August 1, 2004, was published in the *Federal Register*.
July 23, 2004	The start date for the marketing order was deferred to February 1, 2005.
January 4, 2005	Implementation of quality requirements under the pistachio marketing order was delayed until August 1, 2005.
August 1, 2005	All provisions of the marketing order become effective.

certificate. The aim is to be able to trace every certified lot of an individual handler from testing through shipment. Certification of aflatoxin levels done by an accredited laboratory is supposed to certify that no lot of California pistachios shipped domestically exceeds proscribed aflatoxin levels.

Aflatoxins in Pistachios and Other Foods

Aflatoxicosis is poisoning that results from ingestion of aflatoxins in contaminated food or feed.[9] Aflatoxins are a group of structurally related toxic compounds produced by certain strains of the fungi *Aspergillus flavus* and *A. parasiticus*. Under favorable conditions of temperature and humidity, these fungi grow on certain foods and feeds, resulting in production of aflatoxins. The most pronounced contaminations have been encountered in tree nuts, peanuts, and other oilseeds, including corn and cottonseed. Aflatoxins produce acute necrosis, cirrhosis, and carcinoma of the liver in a number of animal species and it is logical to assume that humans may be similarly affected. Aflatoxicosis in humans has been reported only rarely; however, cases of it are not always recognized. One of the most important accounts of aflatoxicosis in humans occurred in more than 150 villages in adjacent districts of two neighboring states in northwest India in the fall of 1974. According to one report of this outbreak, 397 people were affected and 108 people died. A ten-year follow-up of the Indian

9 Information here is taken from the U.S. Food and Drug Administration (2004).

outbreak found that survivors fully recovered with no ill effects from the experience.

In rich countries, aflatoxin contamination in food rarely occurs at levels that cause acute aflatoxicosis in humans, but there have been important aflatoxin events associated with pistachios. Iranian pistachio imports were banned in the EU in September 1997 because of excessive levels of aflatoxins in Iranian pistachio shipments (*The Economist*). The ban lasted nearly three months and was lifted in December 1997 (European Commission, Food and Veterinary Office). However, the demand for pistachios was affected for a longer period. The Food and Agricultural Organization of the United Nations (FAO) has presented data showing that imports into the EU dropped from 102,698 metric tons in 1997 to 59,619 metric tons in 1998.

In 1997, an importing year that was truncated by the ban, Germany imported 47,494 metric tons of pistachios worth $175.3 million and the five-year average leading up to that year (1993–1997) was 43,459 metric tons per year (FAO). In 1998, Germany imported only 18,937 metric tons, just 40 percent of the quantity in the previous year. German imports during the next two years were also well below 1997 quantities—27,059 metric tons in 1999 and only 25,090 metric tons in 2000. The value of the imports fell to $78.9 million, just 45 percent of the value in 1997. This drastic and protracted reduction in imports after the ban was lifted points to a decrease in consumption, perhaps resulting from negative publicity in the media. In 1999, *Oeko-Test*, a German consumer report, reported that eight of eleven samples of pistachios from German supermarkets had higher than allowed aflatoxin levels and that the highest levels were in California pistachios (Hermes).

In the years since 1997, pistachios from several countries have exceeded maximum aflatoxin levels on several occasions, making headlines worldwide. In 2000, Germany alone produced several articles in national (*Der Spiegel*, *Sueddeutsche Zeitung*) and regional newspapers following findings of high aflatoxin levels in pistachio ice cream. Karen Reinecke from CPC supplied various documents detailing the continued appearance of high aflatoxin levels in countries worldwide. For example, one case in Australia dealt with a recall of pistachios following detection of high aflatoxin levels. In February 2000, health officials in Japan found high levels of aflatoxin in pistachios, which resulted in a recall of the product. Also in 2000, aflatoxin testing in France found high aflatoxin levels.

Economic Rationale for Mandated Standards

Mandated collective action programs such as CPC and the proposed California pistachio marketing order use coercive powers of the state or federal government to oblige individual producers to participate and contribute assessments. The programs are voluntary in the sense that their establishment requires support from a sufficiently large majority of producers, but they do not require unanimous support. And, unlike truly voluntary collective action programs such as cooperatives or clubs, these programs, once established, are mandatory for all producers of the commodity in the defined area.

The conventional in-principle economic justification for such use of the government's taxing and regulatory powers is that there are collective goods within the industry—research, promotion, grade standards, packing regulations, public relations, and the like—that will be undersupplied otherwise.[10] In practice, whether the pistachio marketing order will yield net benefits to producers, the state, and the nation as a whole will depend on the nature and extent of "public good" or "external" costs and benefits associated with minimum quality standards and mandatory testing for aflatoxins, along with the other provisions of the order and the costs of implementing the program.

Various elements of the regulations under the marketing order have different types of public-good characteristics, some more easily justified than others. Standardized grades and packaging have

[10] This is the standard public-good argument for government intervention. The goods in question are public goods in the sense that they are nonrival and nonprice excludable, but these public-good benefits are confined to the producers and consumers of a particular commodity and are associated with consumption or production of the commodity. The collective goods could be provided using the general revenues of the relevant state or national government but it is likely to be fairer and more efficient to finance their provision using a tax on the commodity with which the collective goods are associated.

a public-good role in that they reduce transaction costs (e.g., see Freebairn 1967, 1973). An argument for quality regulation can be made where quality is hidden and the market can be spoiled as a result of distortions in incentives to provide and communicate information about quality (e.g., Akerlof). The public-good element is that a consumer's experience with the quality of pistachios from one supplier affects that consumer's subsequent demand for pistachios from other suppliers as well. Especially in the case of a food-quality issue, a bad experience associated with any supplier's pistachios will likely affect the whole industry. The impacts can be large and long lasting, but individual producers will not take these industrywide consequences of their actions entirely into account.

Regulations over visual standards—freedom from blemishes or minimum size regulations, for example—are generally less easy to justify on public-goods grounds since they relate to aspects of quality that are not hidden from consumers. Such regulations may provide *de facto* supply control by diverting some of the volume to nonfood uses altogether or *de facto* price discrimination by diverting a larger proportion of the crop to the processing market, which has a more elastic demand response.[11] One rationale for minimum quality standards for pistachios is that aflatoxins are more often found in small or damaged nuts and eliminating those nuts from the market is an indirect way of reducing the risk of aflatoxins. However, these facts raise a question about whether the policy of direct testing for aflatoxins is effective.

Maximum aflatoxin standards and inspection and certification have a food-safety role, as well as an industry collective-good element, because aflatoxins are a serious, and in some cases deadly, poison. However, the standards proposed by the marketing order are in addition to and tighter than those the U.S. government already has in place for food safety. An industrywide food safety issue could arise as a result of evidence of death or illness associated with consumption of pistachios containing aflatoxins. As with other food scares, there may be consequences for demand experienced throughout the industry, not just by firms directly responsible for such incidents.

The same type of market problem could arise without a case of actual food poisoning. It could result from an aflatoxin event involving discovery of aflatoxins in excess of the 20 ppb allowed by the U.S. Food and Drug Administration (FDA). Even in the absence of an aflatoxin event in pistachios, there could be adverse effects on the pistachio market from perceptions of such a threat generated by adverse publicity associating aflatoxins with pistachios, directly or indirectly, for some other reason, such as when excess amounts are discovered in other products in the United States or anywhere else in the world. Negative perceptions could result from adverse attention to aflatoxins even if no excess amounts were discovered. Negative consequences could result from negative perceptions among final consumers, who then choose not to purchase products; negative perceptions among market middlemen such as retailers that then decide not to stock a product that might be subject to recall or lawsuits; or from governments that prohibit products because of heightened concerns over food safety.

Perceptions of a food quality problem are not specific to individual suppliers; instead, they affect the industry in a collective way. Therefore, the private incentive to assure high quality nuts that are perceived as safe does not reflect the full industrywide or public benefit of these actions. In such cases, voluntary actions motivated by private incentives provide less safety and quality assurance than would be in the interest of the industry (and the general consuming public). In this case, all farms and firms benefit from a stronger reputation for pistachios in general, but their individual actions cannot assure such a reputation unless the rest of the industry matches those actions. Individual farms and firms have private incentive to keep their own direct costs low and invest less in safety testing and quality assurance than would be optimal from the view of the whole market. This is a classic "free rider" problem where individuals cannot

[11] Alston et al. (1995) analyzed the impacts of the allocated-reserve policy applied by the Almond Board of California under a federal marketing order, an example of this type of supply control, which can be mimicked by use of quality regulations to divert some fraction of production from the market. Chalfant and Sexton analyzed an interesting example of *de facto* price discrimination associated with grade standards in the California prune industry.

be precluded from sharing in benefits even if they fail to contribute and where one individual benefiting from the better reputation does not preclude benefits to others.[12]

Two characteristics of the pistachio market make public-good concerns particularly important in the context of food safety assurances and quality standards. First, as with many fresh fruits and nuts, there is little if any brand identification with pistachios. Thus, a customer who has an unsatisfying experience with a purchase of pistachios or who hears negative news about the safety of consuming pistachios is unlikely to associate such concerns with a specific brand or supplier. Unlike branded, packaged consumer items, any negative news would affect not just a specific supplier but the industry at large. Second, many pistachio purchasers consume the product infrequently, purchase relatively small quantities, and have relatively little knowledge about pistachios. One would therefore expect the industrywide reaction to an aflatoxin event in pistachios to be large compared with more familiar foods, especially in the context of food safety concerns. The wholesale trade would be even more sensitive to an event if a recall were necessary.

The result of this reasoning is that the pistachio industry has strong in-principle reasons for acting collectively to assure industrywide compliance with quality and food-safety standards. But this is only an in-principle case. Whether collective action of this type provides net benefits to the industry depends also on how effective the program would be in reducing either the likelihood of a food scare or its severity and on the costs of the program.

[12] Winfree and McCluskey present a formal theoretical analysis of a market for a good with a collective reputation in which they demonstrate a private underinvestment in the collective good.

3. A MODEL OF THE IMPACT OF MANDATED STANDARDS IN THE MARKET FOR CALIFORNIA PISTACHIOS

To assess the costs and benefits for the various groups, we developed a simulation model of supply and demand for California pistachios designed to allow us to represent introduction of the proposed federal marketing order for California pistachios.

3.1. Overview of the Model

The model is used to simulate production, prices, and allocation among markets for California pistachios for 50 years ahead, beginning in the year 2000. Projections are based on historical trends and we use as a starting point, to define parameters, average data for five years, 1997 through 2001, with monetary values expressed in real 2003 dollars. We use a stochastic simulation approach with yields varying over time to reflect alternate bearing and other random influences. Aflatoxin events also occur at random. In the model, both the specified probability of an event and the severity of the demand response to a given event are lower with the marketing order in place. For each "draw" of a time series of future yields, we simulate the outcomes for economic variables in the industry with and without the marketing order; by comparing the two, we measure the consequences of the marketing order in a given draw. By considering 250 draws of future time paths of yields, we are able to estimate the effects of the marketing order on various measures of interest in terms of both average (or expected) values and the range of outcomes (or other measures of variability).

Linear equations representing domestic and export demands for pistachios and storage demand are specified using estimates of elasticities and data on market shares, quantities, and prices. The marketing order applies solely to the domestic market. We assume it would affect domestic demand for pistachios by reducing the probability of an aflatoxin event and the severity of the demand response to a given event. We assume the marketing order would cause higher average quality in the market and provide USDA certification about these improvements.

Introduction of the marketing order would also affect producer and processor costs. These additional costs relate mainly to aflatoxin testing and to meeting quality standards. They are represented in the analysis as a per-unit deduction from grower returns as though it were an assessment on growers.[13] To provide a net benefit, the marketing order must generate a large enough demand response to more than offset the effects of the assessment.

Supply in any year depends on the number of bearing trees and the yield per acre. Current supply does not depend on current price since bearing acreage is predetermined (we assume no tree removals in response to price changes over the ranges being analyzed) and yield is assumed to be insensitive to price. The longer-run supply response is through changes in bearing acreage, which are brought about through plantings made in response to expected future prices (or, more precisely, the expected net present value of an acre of new plantings). Nevertheless, given lags and the way in which we model expectations formation (described in detail later), current production is strictly predetermined in the current market period. The model is solved by equating total demand for California pistachios and the exogenous quantity and solving for price, which we do for each year with and without the marketing order for each scenario and for each of 250 random draws of the 50-year time series of yields. From these results, we calculate the effects on net returns to producers and processors and net costs and benefits to marketers and consumers.

[13] Some elements of costs will be borne explicitly as an assessment while others are an implicit assessment through regulation. For the latter elements, the initial incidence actually will be on processors through a regulatory requirement that entails a cost rather than as an assessment. But we use a competitive market modeling approach in which the consequences will be the same regardless of whether the initial incidence is on processors or producers and we use an average estimate of the cost of compliance as though it were the same across all processors. These assumptions are further justified when we recall that the elasticity of supply in the short run is zero. As such, all of the incidence of compliance with the regulation *must* fall on growers at least in the short run.

In addition to random variation in yields and aflatoxin events, we allow for underlying growth in yields and underlying growth in demand based on an extrapolation of past trends. We also allow for the possibility that USDA certification might lead to a permanent increase in demand. We conduct the stochastic simulations first using our "most likely" selection of parameter values, for which we report detailed results, and then using alternative parameter values to examine the sensitivity of the results to assumptions.

3.2. Supply, Demand, Price, and Market Allocation

The equations of the model are specified as linear forms and they are parameterized using data on initial values of prices and quantities, assumptions about underlying proportional trends in demand and yield, and elasticities. The initial data on prices and quantities are the average actual values for 1997 through 2001 expressed in 2003 dollars, and these values do not vary across alternative simulations. In recognition of uncertainty about values for the elasticities and trend growth rates, as well as about a set of base values, we try alternative values and examine the implications for findings.[14]

Long and sad experience reveals that it is surprisingly difficult to estimate useful elasticities of supply or demand for agricultural products and the precision and robustness of the estimates are often low. (We suspect this same statement applies to such parameters for supply and demand parameters for other products as well.) The signal-to-noise ratio is low in typically available time-series data, where changes in production or consumption attributable to prices are confounded with effects of other variables and where the econometric identification of supply and demand factors is tricky. Cross-sectional variation does not often offer an appropriate alternative because price differences are more likely to reflect quality or market characteristics than an exogenous price in distinct markets. The estimation difficulties are more pronounced on the supply side, particularly because of dynamic responses that imply lags between observed price changes and their realized impacts, such that it is necessary to model decision-making under uncertainty and the formation of expectations. These aspects are particularly pronounced for perennial crops where the production cycle is multi-year and the dynamics are long term.

Increasingly in agricultural policy models, recognition of the limitations of econometric estimation has led to a greater emphasis on the use of assessments based on specific knowledge of the industry, indirect evidence from industry experts, inference from other commodities, and calibration approaches to avoid placing undue reliance on econometrically estimated elasticities. This is particularly true for an analysis that proposes to evaluate policy changes that imply changes in markets outside the range of historical experience (i.e., types that would not be well reflected in an extrapolative approach) or where we want to measure long-run responses, and we recognize that typical elasticity estimates are most likely, at best, to reflect only short- or intermediate-run responses.[15]

These observations are especially pertinent for the present context. We have in mind to simulate responses over a comparatively long period of time to policy changes that can be regarded as fully anticipated and permanent in nature. For this kind of policy change, we seek to measure long-run responses of the type that generally cannot be estimated directly, especially for perennial crops, and we have in mind to simulate a policy change that goes outside the range of past policy change. In addition, we are dealing with an industry that is comparatively young and has been growing comparatively quickly, providing fewer than 25 years of annual time-series data. Moreover, it cannot be argued that the structure has been stable over

[14] A number of studies have estimated supply and demand elasticities for elements of the fruit, nut, and vegetable sector. For instance, see Alston et al. (1995, 1997, 1998) or Huang (1985, 1993).

[15] This latter feature of econometric estimates of elasticities of supply response was discussed more than 70 years ago by Cassels as a likely consequence of the inherent dynamics of supply response combined with unobservable intentions and expectations on which they are based. The issue has been acknowledged in several reviews since then (e.g., Colman; Just and Pope; Nerlove and Bessler) but less often in individual supply-response studies. A further issue for policy analysts, known as the "Lucas critique," arises when policy itself is embedded in the observed responses and the estimated parameters—see McDonald and Sumner.

the period or that the market has been in long-run equilibrium.

We have conducted econometric analysis that provides some information about elasticities. Nonetheless, to define the structure of the model and likely values for its parameters, it is necessary to use considerable judgment—based on theory and knowledge of the industry, its markets, and technology—to augment and filter the limited amount of information that can be gleaned from econometric analysis.

Model of Investment and Supply Response

Models of supply response for perennial crops are reviewed in detail by Alston et al. (1995). The more theoretically defensible models partition the supply response into separate equations representing elements of yield per bearing acre and the number of bearing acres (or other measures of the stock of bearing trees) with adjustments to bearing acreage reflecting planting and removal of trees with a lag to reflect the time it takes for trees to mature and come into production.

Based on knowledge of the pistachio industry and the literature, we take a fairly conventional approach and assume that the only supply response to price changes in our analysis is through plantings. In the case of pistachios, the trees are comparatively long-lived and, given how relatively young the industry is in California, removals for replacement are not expected to have a substantial impact on the stock of trees over the period of our analysis.[16] In addition, given the relatively modest range of economic changes being analyzed, we do not expect to see any removal response to changes in price induced by the policy. Most studies of supply of perennial crops do not allow for a removals response to prices and those that do allow for it usually do not find evidence of a significant response; the same is true for yields. We include in the model a fixed removal rate of 1 percent per year, which is consistent with recent history, and we increase this rate to 2 percent per year after 2015 to reflect increases in the average age of the bearing stock.[17]

Some of the literature has argued for a modeling approach based on neoclassical investment theory, and we have adopted an approach based on that argument (see Akiyama and Trivedi (1987) and Dorfman and Heien (1989) as reviewed by Alston et al. (1995)) combined with elements of rational expectations to model investments in new plantings.

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

$$(1) \quad PV_t = \sum_{n=0}^{\infty} \pi_{t+n}(1 + r)^{-n}$$

where PV_t is the present value in time t of the stream of net revenue generated by the investment in a new acre of trees planted in time t; π_{t+k} is the net return to the plantation in the year $t+k$—i.e., k years in the future; and r is the real discount rate.

In the benefit-cost analysis, we use a real social rate of return of $i = 4$ percent per annum to discount the streams of benefits and costs. In the growers' maximization problem, however, we use a value of $r = 5$ percent per annum as the real discount rate. This discount rate includes a modest (1 percent) risk premium relative to the risk-free real rate used in the benefit-cost analysis. In practice, we truncate the stream of benefits at 50 years in the future, which may be taken as reflecting a view that the effective life of the orchard is 50 years.[18] This truncation was motivated by a desire to reduce the size of the large data

[16] In personal communications, Louise Ferguson (an extension specialist in the Department of Pomology at the University of California, Davis) (November 5, 2003) indicated that the economic life of pistachio trees is limited only by the ability of the branches to withstand tree shaking during harvest, which should not be a problem for the first 50 years of life, and therefore she could not foresee any significant replanting of pistachio trees for some decades to come.

[17] This discrete shift could be replaced with a gradual increase from 1 percent to 2 percent, but we would not expect to see much change in the results.

[18] The productive life expectancy of trees is more than 50 years, but we have allowed a 2 percent depreciation rate reflecting losses from disease and other causes, and trees can become obsolete for various reasons. An alternative view is that growers have a 50-year planning horizon and do not count benefits beyond 50 years in the future. This view is not strictly consistent with the rational expectations approach in which the terminal value of the orchard should be included when we fix the horizon arbitrarily at 50 years. However, when combining a 5 percent discount rate and a 2 percent depreciation rate (an effective overall discount rate of 7 percent), the contribution to the present value from returns beyond 50 years is quite small.

files being generated by the simulation, but it does create some complexity in appropriately comparing streams of costs and benefits given the lags between initial investment and the long streams of resulting benefits. This aspect is discussed later.

The stream of net returns depends on per-acre yields (*Y* pounds per acre), the output price (*P* dollars per pound), and variable costs per acre, *VC*, according to:[19]

$$(2) \quad \pi_{t+n} = P_{t+n} Y^{n}_{t+n} - VC_{t+n} .$$

In this equation, Y_{t+n} is the yield of trees planted in year *t* that will be *n* years old *n* years hence (the subscript refers to the future date and the superscript refers to the age of trees at that date). In our analysis, it is reasonable to assume that the variable costs per acre will be viewed as constant in real terms, whereas the output price and yields will be expected to vary. The expected yields from the newly planted trees will vary in predictable ways as the trees age, and the output price will vary in response to shifts in supply and demand, some of which are predictable based on information that is currently available (the current stock of nonbearing trees, for instance).

We use a representative-firm model in which the firm takes account of the effects of its planting decisions on both the cost of new plantings and on the future time path of output and prices. Assuming rational expectations, as described hereafter, the time *t* expectation of net revenue in time *t*+*n* can be written as:

$$(3) \quad E_t \pi_{t+n} = E_t (P_{t+n} Y^{n}_{t+n}) - VC .$$

The investment decision involves comparing the expected present value of the stream of net income with the cost of the new plantings, which includes the cost of the planting material and the cost of the labor and capital and other inputs used to prepare the land for planting and to plant the trees.

In the formation of expectations of the net present value of investment in new plantings, we use information on the yield-age profile of trees, which can be treated as not varying in general shape over time. That is,

$$(4) \quad E_t Y^{n}_{t+n} = y_n E_t YM_{t+n}$$

where y_n is the yield of an acre of trees aged *n* years as a fraction of the yield of an acre of mature bearing trees, YM_t.

We assume that the investment cost (*C*) is a quadratic function of the rate of new plantings (*PL*). Mathematically,

$$(5) \quad C_t = c_1 PL_t + \tfrac{1}{2} c_2 PL_t^2 .$$

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

$$(6) \quad AC_t = c_1 + \tfrac{1}{2} c_2 PL_t; \;\; MC_t = c_1 + c_2 PL_t .$$

The values of the parameters of the total, average, and marginal cost functions (c_1 and c_2) are derived based on information from cost and return studies prepared by the University of California (UC) Cooperative Extension (Beede et al.; Kallsen et al.) on costs and returns for investment in pistachios combined with the equilibrium condition under which the expected present value (from the model) is equal to the current marginal cost of new plantings.

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

$$(7) \quad \underset{PL_t}{Max}\, E_t NPV_t = PL_t (E_t PV_t - AC_t) .$$

[19] In this approach, variable costs do not depend on yields or the age of the trees. Our inspection of cost and return studies prepared by the University of California Cooperative Extension (Beede et al. and Kallsen et al.) for pistachio production indicates that this is a reasonable approximation for bearing trees regardless of their age. We apply a different approach for nonbearing trees, for which costs are incurred but no revenue is obtained. In practice, we treat all costs incurred during the nonbearing phase as an element of the initial investment in a new planting.

The first-order necessary condition for a maximum is that marginal benefit (per acre) equals marginal cost:

$$(8) \quad E_t\, PV_t = MC_t\,.$$

In these equations, planting decisions are based on expectations of prices, yields, and so on over the indefinite future. Inherent in these expectations is knowledge not only of the parameters of the supply side of the model—including yield relationships and the dynamics of the stock of bearing trees as well as the determinants of plantings represented in Equations (1) through (7)—but also knowledge of the parameters of the demand side. It is not practicable to solve our specific structure analytically for the supply-response model implied by rational expectations. Instead, we use an iterative numerical simulation process. Before we describe that process, we elaborate on the other elements of the model.

Bearing Acreage

Bearing acreage evolves according to

$$(9) \quad B_t = (1 - f_t)\, B_{t-1} + PL_{t-5}$$

where B_t is the bearing acreage in year t, which is equal to the value in the previous year less the amount removed in that year, which is defined by the proportional removal rate f_t (remember, we assume f_t is 0.01 for years up to 2015 and 0.02 thereafter) plus an increment equal to the number of trees planted in the year five years previously.

Yield per Bearing Acre

Yields per bearing acre of mature trees vary over time, reflecting both the alternate bearing habit of pistachios and the influence of other random variables. Yields also trend up to reflect technological improvements. To capture these characteristics, we use a trend model of the following form:

$$(10) \quad YM_{t+n} = (1 + g)^n\, YM_t\, (1 + u_{t+n})$$

where YM_{t+n} is the projected yield per mature bearing acre in year $t+n$, which is equal to the value in the base year, YM_t, scaled up by exponential growth at a rate g and adjusted by an annual proportional shock, u_{t+n}.

The values for u_{t+n} are obtained by first computing the past values of year-to-year variations around trend yields. We extend that series to a length of 100 observations by replicating the sequence and then draw a series of 50 by selecting a starting point at random within the 100 observations. This series represents one 50-year sequence of random shocks that, when combined with Equation (10), allows us to generate a single "future" of yields over 50 years. Alternative futures are generated by drawing alternative starting points. We generate and use a total of 250 such futures in the simulation models.

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

$$(11) \quad Y_t = \left[1 - \sum_{n=6}^{10} (1 - y_n)\left(\frac{PL_{t-n}}{B_t}\right)\right] YM_t$$

where, as noted, y_n is the yield of an acre of trees aged n years as a fraction of the yield of an acre of mature bearing trees.

Production

Production is simply the product of yield per bearing acre from Equation (11) and the number of bearing acres from Equation (9):

$$(12) \quad Q_t = Y_t \times B_t\,.$$

Demand Equations

Annual demand consists of two distinct markets, the domestic and the export market, which are treated differently by the marketing order. Demand also includes demand for changes in stocks. We specify linear equations for quantities demanded on the domestic market (DD_t), on the export market (DE_t), and for storage (DS_t) t years in the future as a function of the price of pistachios (P_t) in that year as follows:

$$(13)\quad \begin{aligned} DD_t &= (d_0 - d_1 P_t)(1 + d)^t \\ DE_t &= (e_0 - e_1 P_t)(1 + e)^t . \\ DS_t &= (s_0 - s_1 P_t)(1 + s)^t \end{aligned}$$

Values for the slope and intercept parameters for each of these equations are estimated using elasticities and initial values for prices and quantities in the base year using five-year averages (1997–2001). Values for the growth rate parameters (d, e, and s) were chosen to reflect underlying growth rates in demand (reflecting the influence of growth in population, per capita income, other demographic variables, and other trend factors such as prices of other goods and preferences). Initial values for these were set at 3.6 percent per annum in each case in view of past trends in consumption and after allowing for the effects of trends in prices.

Values for the demand elasticities are based on a combination of econometric estimates in the literature, our own econometric estimations, and our judgment based on knowledge of the pistachio industry and other agricultural industries. Lewis conducted a statistical analysis of pistachio demand response and found elasticity values ranging from −1.59 to −2.31 for export demand and from −1.14 to −1.66 for domestic demand. We estimated models of demand for U.S. pistachios in aggregate and for U.S. consumption and obtained some reasonable results and plausible elasticities. In a range of specifications, we estimate the overall elasticity as about −2 and the domestic elasticity as about −1. These estimates are consistent with elasticities of demand for exports and storage of about −3, which are plausible.

The storage model warrants some brief elaboration. Pistachios may be stored from one year to the next as a speculative response to accommodate alternate bearing and other somewhat predictable supply and demand shocks or for other purposes that fit under the rubric "convenience yield." Storage response is important in our context because increased storage may be an important mechanism by which the industry can absorb a *temporary* demand shock. Our representation of storage response is necessarily simple, but it is a better option than treating storage as exogenous and not relevant to the analysis of the consequences of a demand shock.

In specifying the simple linear model of demand for stocks, we opt not to apply any specific formal model of storage behavior, such as a model based on rational expectations or some form of an efficient-markets hypothesis. In our specification, the demand for stocks slopes down such that current stocks will be greater when the current price is lower—a view that is consistent with various models of storage behavior and its motivations. Our limited econometric analysis gave some support to this view prior to implementation of the simulation analysis, and further support can be taken from a consideration of the results of the simulations as documented in Appendix Table A7.

Using the mean of the simulated values in the baseline scenario (discussed in Section 4), we compute the change in stocks each year and, using the simulated prices, the value of the change in stocks each year. This can be seen as the gross annual profit from speculative stockholding; computing net profits would require deductions for costs of storage, losses in storage, and "in and out" charges, but we do not have data on these costs. We compute the net present value of these gross stock trading profits using a real discount rate of 5 percent per annum (as used for other elements of the producer problem) as −$114.7 million; using a discount rate of 10 percent instead, the present value is −$18 million. That is, the storage behavior predicted by the model involves a loss to producers (storers). Over the 50-year horizon, the model predicts that a relatively constant share, about 24 percent of the crop, will be stored from year to year and that the gross loss from storage (not counting storage costs and so on) is worth about 1.3 percent of the value of the crop. Essentially, this results from the long-term trend of falling prices such that storage is, on average, a losing proposition. The fact that relatively more is stored in high-output (low-price) years and relatively less in low-output (high-price) years mitigates but does not eliminate the fundamental trend.

We compared this pattern with the actual storage behavior in the previous period, 1979–2001. To put the figures on an equal footing, we compared those 20 years with the first 20 years in the simulation, 2000–2020. The results in Appendix Table A7 are reassuring. In the actual data, stocks as a share of production averaged 37 percent between 1979 and 2001 (compared with a simulated 24 percent between 2000 and 2020); the actual quantity stored was somewhat more volatile than the simulated quantity stored. Using a 5 percent discount rate, the present value in 1979 of gross stock trading losses between 1979 and 2001 was $50 million (compared with a simulated present value in 2000 of stock trading losses for 2000–2020 of $49 million), and these actual losses were incurred in a significantly smaller industry than that simulated over the subsequent period. The gross characteristics of the simulated storage behavior are consistent with those of the past: a significant share of production carried over from one year to the next and significant trading losses on stored pistachios. Presumably these losses are incurred in order to earn some other market advantage, such as ability to meet unexpected demand or other elements of "convenience yield."

Market Equilibrium

The sum of the three elements of demand represents the total demand (i.e., $D_t = DD_t + DE_t + DS_t$), which can be solved for price to obtain the inverse demand equation as follows:

$$(14)\quad P_t = \frac{d_0\,(1+d)^t + e_0\,(1+e)^t + s_0\,(1+s)^t - Q_t}{d_1\,(1+d)^t + e_1\,(1+e)^t + s_1\,(1+s)^t}.$$

Then, substituting for Q_t from Equation (12), which depends on the stock of bearing trees from Equation (9) and realization of the stochastic yields from Equations (10) and (11), we can solve for the market clearing price.

Model Solution Procedure

The model solution procedure followed an iterative recursive process for a given policy scenario. First, a set of starting values was chosen for the stream of expected net present values per acre. The set of starting values implies a stream of plantings (which do not depend on the unpredictable, stochastic elements of yields) over the 50-year planning horizon of 2000–2050. Then, using that stream of plantings, we projected the stream of bearing acreage over the next 100 years.[20] Combining the stream of projected bearing acreage with each of the 250 streams of yield futures, we computed the corresponding 250 future streams of annual gross and net revenues both in total and per acre. From these future streams, we computed the average, or expected, stream and then the expected present value of investments for each of the 50 years, 2000–2050. Next, we used these solutions to replace the starting values and repeated the process. The process was iterated until the solution did not change appreciably—that is, the expected stream of revenue in total and per acre used to generate the stream of plantings was equivalent to the expected stream of revenue in total and per acre implied by the stream of plantings. It is in this sense that the model entails rational expectations. The same procedure was also used with alternative parameterizations (but the same yield draws) to simulate the market under alternative policy scenarios.

3.3. Price, Quantity, and Economic-Welfare Impacts

Producer benefits associated with the policy are computed (as differences compared with a no-policy base) for each scenario and for each year of the simulation as the change in profit or producer surplus. The supply response was derived from maximization of the expected net present value of profits, and we computed the expected (or average) net present value of producer net returns as an element of the model solution procedure. This requires two modifications before it can be used as the measure of producer benefits in the social benefit-cost calculus. The first modification is to the discount rate. For the producer optimization, we incorporated an allowance for risk and used a discount rate of 5 percent per annum. For the aggregate benefit-cost analysis, we used a smaller discount rate of 4 percent, leaving out the risk premium.

The second modification is made because we opted to evaluate the benefits and costs of the marketing order over the 2000–2050 50-year horizon (this is

[20] Plantings in year 2050 depend on expected returns over 2051–2100 and hence the 50-year planning horizon entails projections over 100 years. In practice, we solved the model for the first 50 years and then projected the values for the 50th year forward for an additional 50 years as though a steady-state solution had been reached in year 50.

implied by the decision to truncate the stream of benefits using that horizon). The decision to truncate the benefits at 2050 implies making an adjustment to the stream of costs of new plantings to make it comparable to the stream of benefits. For instance, the stream of costs includes the costs of plantings made during the last six years of the simulation even though they cannot have generated any benefits within the 50-year horizon. Those costs are associated with an investment that will yield benefits that will be realized after the end of the 50 years and it is therefore inappropriate to include them in the benefit-cost calculation. Similarly, trees planted in the last 20 years of the 50-year horizon will generate most of their benefits after the end of the 50-year period, and any tree planted after 2001 will have some of its benefits accruing after 2050. Hence, we discounted the costs of planting and progressively more so for later plantings. To do this, we developed and applied a procedure to apportion planting costs incurred in each year of the simulation according to the fraction of the total expected benefits (measured in present value of benefits in 2000) from that planting that would accrue prior to 2050.[21]

Annual domestic consumer benefits were computed as changes in Marshallian consumer surplus (the area behind the domestic demand curve), reflecting the effects of both price changes and shifts in the demand. Annual national benefits are equal to the sum of producer and consumer benefits.

The annual producer, consumer, and national benefits were discounted back and expressed in present-value terms. The producer benefit-cost ratio is computed as the ratio of the present value of producer net benefits divided by the present value of the producer incidence of the assessment to finance the policy. Another index of the economic impact of the policy is the national benefit-cost ratio, which is computed as the present value of national benefits divided by the present value of the cost of the program. (The cost of the program includes the cost of both the assessment to finance the program and other costs of compliance with the program, both of which are represented in the model as though they were included in the assessment, as discussed in the next section.) We express the benefit-cost ratios for both producers and the nation as net benefits per unit cost. A more conventional benefit-cost ratio, which expresses gross benefits per unit cost, can be obtained by adding one to the ratios we report.

3.4. Representation of Effects of the Marketing Order

The marketing order imposes regulations that entail costs of compliance, borne in the first instance by processors, and other costs that are to be financed by an assessment on processors. The provisions of the marketing order are designed to improve marketing conditions and increase the demand for pistachios on average and thereby to provide benefits to the industry that will more than offset the cost of compliance. The potential increases in demand, on average relative to a scenario without a marketing order, include the effects of (1) a reduced probability of a negative shock to demand associated with an aflatoxin event and a reduction in the size of the negative shock associated with a given event, and (2) an increase in demand in every year owing to greater consumer (and buyer) confidence in the product associated with USDA testing and certification. In this section, we discuss these two demand elements, but first we turn to the cost of compliance they are meant to offset.

Cost of Testing and Other Compliance Issues

The quantitative economic analysis requires information on the costs of aflatoxin testing and compliance with other quality standards as regulated under the marketing order. The initial incidence of these additional costs will be on the processing sector. Depending on their current level of testing and other characteristics, processing firms face different costs of complying with the proposed standards under the marketing order—in essence, the cost of aflatoxin testing of pistachios destined for the domestic market and of meeting quality standards. A

[21] Using discounting procedures, we computed the fraction of the total net present value of benefits from an investment in a new planting accruing before (and the fraction that will accrue after) any given number of years in the future (for instance, for up to six years into the future, the fractions will be zero and one). Hence, we estimated the fraction of total expected benefits that will accrue within the period 2000 through 2050 and the fraction that will accrue after 2050.

telephone conference with the seven major processors in California provided data on the cost that various processors in the California pistachio industry would face under the proposed marketing order (Pistachio Processor Group). In his testimony at the July 2002 hearings, Sumner described in detail how to estimate these costs for three different types of processors depending on their current testing practices and the size of their processing operations and based on labor requirements and wage rates for inspectors, lot sizes, and various other factors. The resulting estimate of the direct per-unit cost of compliance was a weighted average (across the different types of processors) of $0.00525 per pound on the two-thirds of production to which the proposed marketing-order rules would apply. This figure seems to be a consensus estimate in the industry.[22] The weighted cost of compliance applied across all of California's pistachio production is $0.0035 per pound. These figures are based on an assumption that few undersized pistachios are currently sold in the standard market such that implementation of the other features of the marketing order would not have a significant impact on the total quantity available to the domestic market.[23]

Effects on the Probability of an Aflatoxin Event and its Consequences

Direct evidence does not exist on the probability of an aflatoxin event that would cause a major negative shock to demand when it occurred or on the likely severity of the shock. We assume that increased aflatoxin testing would reduce the probability of such an event and could reduce the severity of the shock as well, but, again, we have no direct quantitative evidence on the relevant magnitudes. To calibrate the potential effects of a pistachio food scare, we use information from other produce-related food scares in the United States along with information from an event involving pistachios in Germany, and we conduct some sensitivity analysis in which we vary the relevant parameters.

Many produce-related food scares have occurred, and these give some guidance about the potential size and duration of the response to an aflatoxin event in pistachios. For the period from 1990 to 1999, the Center for Science in the Public Interest (CSPI) lists 55 cases in the United States alone. A recent produce-related food scare involved cantaloupes and *Salmonella* in 2000, 2001, and 2002. Because of potential health risks stemming from *Salmonella* that had infected several people in the United States and Canada, certain cantaloupe brands were recalled nationwide (U.S. FDA 2003). In 1996, the California strawberry industry lost an estimated 5 percent in total revenue because of a *Cyclospora* scare (details can be found in Calvin). An earlier, well-known event demonstrating the public's sensitivity toward food quality was the Alar scare in apples in 1989. A television broadcast reported that Alar was used in apple production and that it was the "most cancer-causing substance in the food supply." Apple demand dropped dramatically overnight and apple growers suffered losses estimated at hundreds of millions of dollars (details can be found in van Ravenswaay and Hoehn).[24] The American Council on Science and Health (ACSH) reported that the effects from the scare could still be felt even five years later and that the market had not fully recovered.

Some direct evidence is available on the market response to an aflatoxin event in pistachios but not for an event in the United States. As described earlier, the EU banned pistachio imports for three months in the last quarter of 1997 because of aflatoxins. After the ban was lifted, German imports were substantially reduced—estimated in the range of 40 to 50 percent—over the next three years. The pistachio market is relatively small and other nuts and snack foods are likely to be close substitutes for pistachios. This may be why the losses for pistachios in the EU market were larger than observed in some other food

[22] The *Federal Register* (USDA, AMS 2003a, p. 46017) reports that "The average cost of compliance, as identified by several witnesses and reiterated in Dr. Sumner's analysis, is approximately one half cent per pound of domestic pistachio production, or $0.00525 per pound."

[23] In any event, under the marketing order, undersized pistachios could still be diverted to the export market and so the consequences of this element of the regulations for prices, quantities, and values would be negligible.

[24] Additional studies of the demand impact of food safety events and information on demand can be found in Smith, van Ravenswaay, and Thompson; Brown and Schrader; Richards and Patterson; and Piggot and Marsh.

scares in the United States, but the differences also may reflect some differences between the United States and other countries—in terms of institutions and consumer behavior—that mean their responses would be different.

Taking a conservative approach, we assume that an aflatoxin event in the domestic market for U.S. pistachios in year *t* would cause a 30 percent reduction in demand in the year of the event (i.e., $\delta_t = 0.3$). The German evidence suggests that the negative demand effects from a single aflatoxin event would continue to affect demand for several years. In the model, the negative demand shock decays at a rate of 30 percent per year (i.e., $\delta_{t+n} = 0.7^n \delta_t$).

Aflatoxin events do not happen every year, but the market always faces some probability of a negative food scare. The proposed marketing order cannot eliminate the chance of a food scare associated with aflatoxin in pistachios, but it does have provisions that make such an event less likely. The benefit from additional testing is a reduction of the probability of an aflatoxin event or food scare. For the current base case of no mandatory testing, we use an annual probability of 4 percent for an outbreak that affects demand as previously specified. We assume that, with mandatory testing, the chance of an aflatoxin outbreak falls to 2 percent (Sumner). We further assume that any events that do occur will have smaller effects on demand. We assume an initial downward shock of 15 percent with the marketing order rather than the 30 percent when no marketing order is present.

Effects on Consumer and Buyer Confidence

The demand for pistachios could be higher as a result of official USDA certification ensuring a good quality product. Many agricultural products take advantage of USDA grading and other services (USDA, AMS 2003a). Buyers for major food outlets are familiar with USDA standards, as are many consumers. In general, USDA's standard-setting is thought to convey a positive benefit in a market as reflected by use of this claim in product promotion, labels, and displays. We are not aware, however, of empirical evidence of the magnitude of the impact of certification. Here, we use a small increase in demand to reflect higher buyer confidence in pistachios due solely to USDA's participation in the standards process.

In addition, but similarly, demand for pistachios will be greater with mandatory minimum quality standards and better buyer perceptions of safety. These standards will reflect well on the product as a whole and shift out demand for all pistachios because buyers will perceive a lower probability of acquiring low-quality shipments. This demand effect also has two aspects. The first is the general notion that buyers are willing to pay more for higher-quality nuts. Second, the minimum quality standard assures buyers that they have a smaller chance of a low-quality shipment. This effect relies on more information being available to buyers that all pistachios from the marketing-order area meet minimum standards. One of the provisions under the proposed marketing order prohibits sales of inferior pistachios. Although these represent a tiny fraction of total production, removing them from the market altogether will result in an increase in the general quality of pistachios, albeit a small one.

To reflect both these elements in the simulations, we allow for a small increase in demand in every year relative to the base case in response to introduction of the marketing order: an increase in U.S. consumers' willingness-to-pay for pistachios equal to 1 cent per pound (about 1 percent of recent prices).

4. RESULTS AND INTERPRETATION

The stochastic model was used to simulate the key economic variables in the U.S. pistachio industry over 250 equally likely random futures. To estimate the impact of the marketing order, we computed and compared a pair of simulations (i.e., one with and one without the marketing order) for each of a number of different scenarios.

The pair of simulations with the most plausible set of model parameters is referred to as the "baseline scenario." The baseline scenario is presented in some detail in Section 4.1, where we describe both the dynamic and stochastic impacts of the marketing order. In Section 4.2, the results of the sensitivity analysis are presented. In this analysis, the baseline scenario is compared to a number of other scenarios to determine how key results are affected by changes in parameters and other modeling assumptions. The sensitivity analysis also provides many comparative dynamic results that further illustrate some of the key economic relationships captured by the model.

4.1. Baseline Scenario and Results

The baseline scenario compares future simulations of the pistachio industry with and without the marketing order. Given that the baseline scenario is built on our most likely parameter values and modeling assumptions, it provides our best estimates of the future path of the industry and how this future will most likely be affected by the marketing order.

Describing the output for a scenario is challenging given that the dynamic and stochastic nature of the modeling process results in a great many numbers. For any given future, the model determines a market clearing price, bearing acres, acres planted, yield, production, domestic quantity demanded, export quantity demanded, ending stocks, revenue, and consumer surplus for each year of the simulation. To capture the effects of random yield variability and aflatoxin-related demand shocks, the stream of simulated equilibrium values was calculated for a set of 250 equally likely futures that differed in terms of values for randomly generated yields and aflatoxin shocks. Finally, for each future in a given scenario, to simulate the impact of the marketing order, a pair of simulations with and without the marketing order was run. Hence, for a given scenario, each simulated variable of interest has a 50-year time path with a random distribution in each period that is affected by the marketing order. In reading the summary statistics and information on average impacts that follow, it is important to keep this time path and the random nature of the variables in mind.

The average production and average number of bearing acres for each year in the baseline scenario are charted in Figure 4.1 and average prices for each year (among other things) are charted in Figure 4.2. The simulation is consistent with the history of the pistachio industry in California, which has been characterized by growth in bearing acres and yields that has been accompanied by declining real prices. Despite some supply response to lower prices, bearing acres and production continue to grow at a pace that exceeds the growth in demand, resulting in a continued general decline in prices.

The average prices, production, and bearing acres shown in Figures 4.1 and 4.2 are average values from the 250 simulated, equally likely futures. The time path in any given random future is more subject to yield and demand variability. Figure 4.2 compares the average prices reported previously to simulated prices in one particular random future. The year-to-year variability in prices of the single future, which is driven by variable yields, is much greater than the variability of the average shown in Figure 4.2 and more consistent with historical variability, which is shown in Figure 2.3. The top and bottom lines in Figure 4.2 plot the ninety-fifth highest and the fifth highest price in the 100 baseline simulations, clearly illustrating the range of prices generated for each year of the stochastic simulation.

Demand shocks related to random aflatoxin events were also simulated in the baseline scenario. The demand shock was modeled as a 30 percent contraction in domestic demand and a 6.6 percent reduction in foreign demand (a 30 percent shock applied to half of the EU market based on an EU quantity that is 43 percent of U.S. exports—30 percent × 0.215 = 6.6

percent). In the baseline scenario (without a marketing order), we assumed a 4 percent probability of such an event in any given year. Given the large year-to-year variability in yields and prices in a simulated future, it is difficult to see the impact of a simulated aflatoxin demand shock in any particular future. In Figure 4.3, the impact of a single demand shock in year 25 is isolated by removing the effects of yield variability. As shown in Table 4.1 and Figure 4.3, the demand shock results in a price decrease of 7 percent while the

Figure 4.1. California Bearing Acres and Production of Pistachios in the Baseline Scenario, 2000–2050

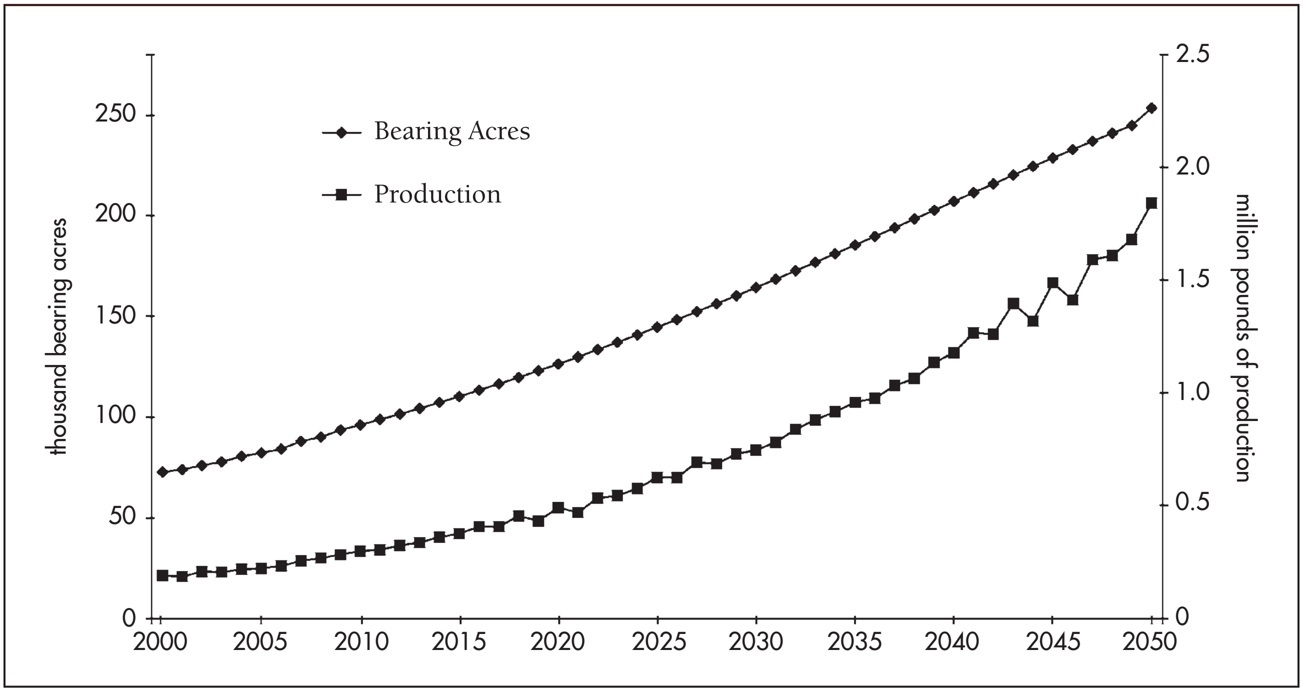
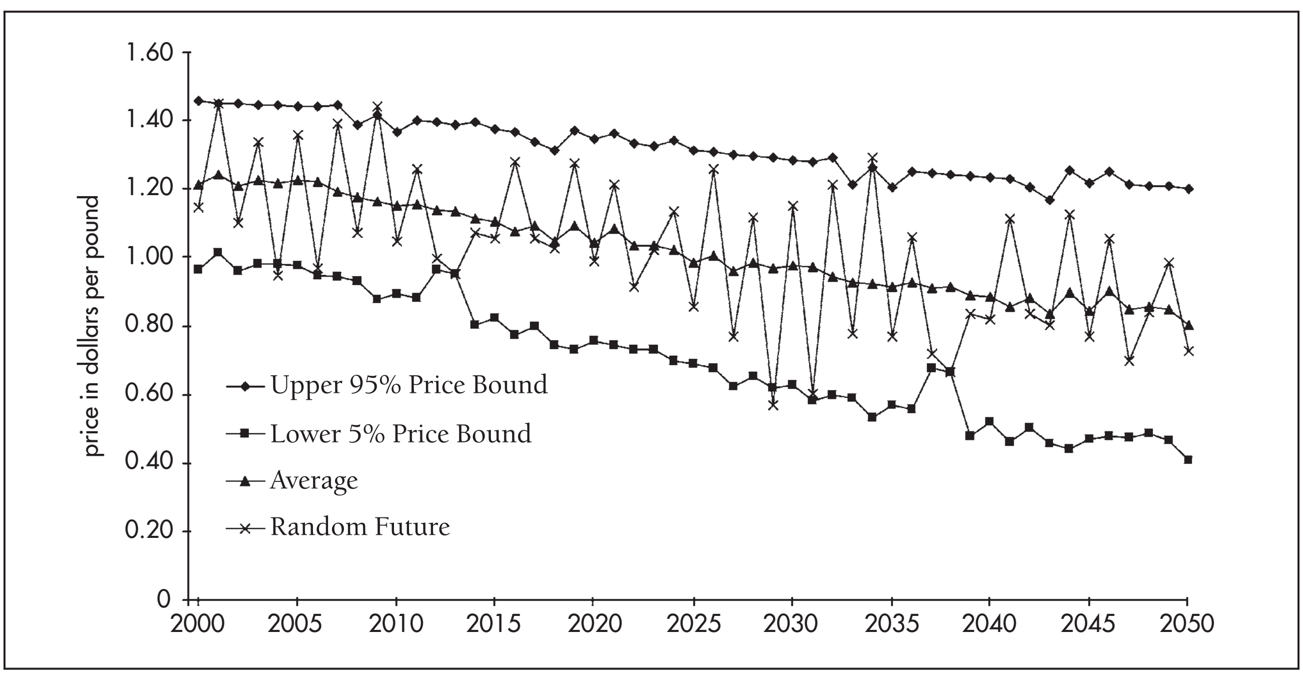


Figure 4.2. Comparison of Reported Real Average Price with Simulated Prices in One Particular Random Future, 2000–2050



quantity consumed domestically falls by 11 percent and the quantity exported increases by 7.9 percent. In the years following the shock, the effects continue but diminish gradually, reflecting the decay in the demand shock caused by the aflatoxin event.

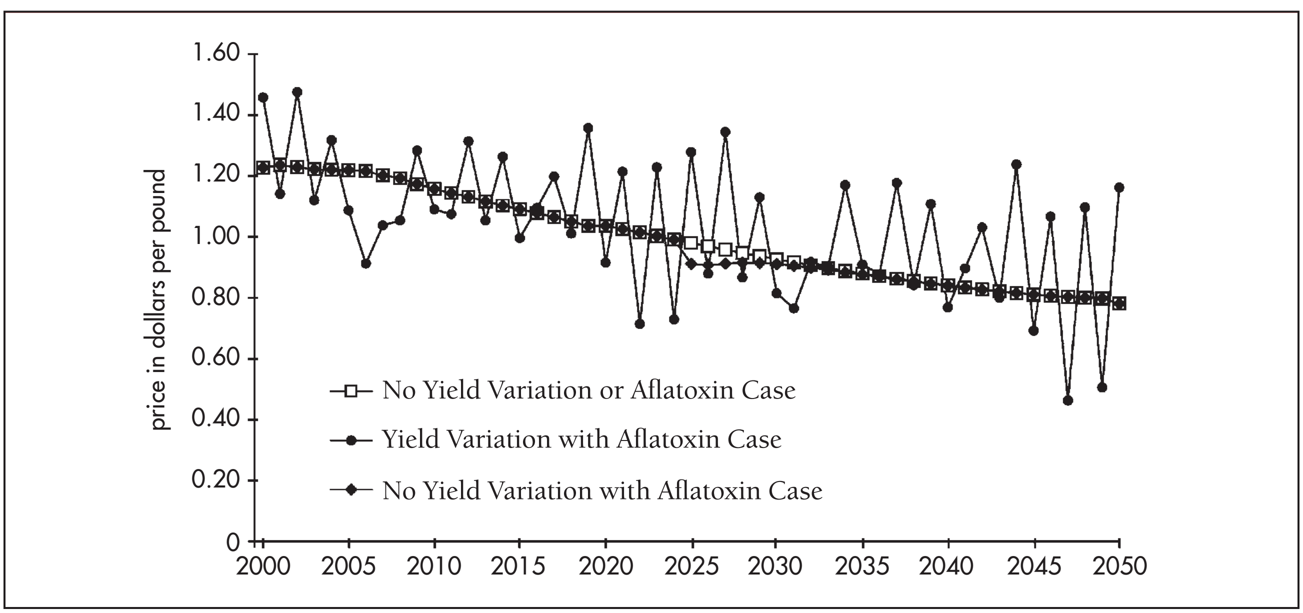
The impact of the marketing order in the baseline scenario was estimated by comparing the baseline simulation with a marketing order to the previously reported baseline simulation without a marketing order. In the case of the marketing order, the annual probability of an aflatoxin event was reduced from 4 percent to 2 percent and the demand impact of such an event was assumed to be half as large (i.e., an initial drop of 15 percent in demand versus 30 percent applied to both the domestic market and relevant export markets). In addition to this benefit, the marketing order was assumed to increase domestic consumers' willingness-to-pay for pistachios by 1 cent per pound. The cost of compliance with the marketing order, 0.525 cents per pound consumed domestically, is reflected as a reduction in the price to growers from domestic sales. Finally, as described in Section 3, we assumed that producers will anticipate the benefits of the marketing order and the planting responses of their fellow growers.

The impacts of the marketing order in the baseline scenario are summarized in the first column of Table 4.2. To summarize the effects of the marketing order over the 50-year simulation, we report average effects over the 50 years for some variables and for others we report the net present value in 2004 of the effects over the 50 years. In the baseline scenario, over the 50-year horizon and relative to a no-policy base, the policy modestly increases the average return to growers, along with the average number of bearing acres

Table 4.1. Domestic and Export Demand and Price Effects of an Aflatoxin Event in 2025

	Percent Change in		
Year	Domestic Demand	Export Demand	Price
2024	0.00	0.00	0.00
2025	−10.96	7.92	−6.99
2026	−6.71	7.66	−6.35
2027	−4.47	5.69	−4.76
2028	−3.06	3.99	−3.42
2029	−2.13	2.76	−2.43
2030	−1.48	1.91	−1.72
2031	−1.03	1.32	−1.23
2032	−0.72	0.91	−0.87
2033	−0.50	0.63	−0.62
2034	−0.35	0.44	−0.44

Figure 4.3. The Impact of a Demand Shock on the Grower Price of Pistachios



(by 1,669 acres) and production (by 8.62 million pounds per year).[25] These increases in production are associated generally with an increase in domestic consumption (by 9.92 million pounds per year) and decreases in both exports (by 1.25 million pounds per year) and stocks (by 1.30 million pounds per year). These averages mask the fact that, as noted previously, the effects on some of these variables change over time both because of trends (such as the production response to the policy, shifts in the incidence, and increases with time, as opposed to the domestic demand response, which begins immediately) and from year to year (through the interaction of policy-induced changes in bearing acreage and variable yields). This is true in particular for the effects of the policy on exports—the small average effects reflect negative impacts in some years, especially initially, and positive impacts in others, especially in later years.

The marketing order increases grower price and revenue per acre by increasing consumer confidence and reducing the odds and the impact of an aflatoxin event. As shown in Figures 4.4 and 4.5, the dynamics of the consequences are complicated because of the dynamics of supply response to price. The impact on revenue is greatest in the first few years after introduction of the marketing order because supply is unaffected for this period of time. As shown in Figure 4.6, the increase in revenue per acre eventually causes an increase in the time path of bearing acres. The increase in bearing acres results in increased production, driving down prices and revenue per acre and dissipating the benefits for producers. Consumers gain initially from improved food safety and these benefits are then augmented by subsequent reductions in prices resulting from the increases in production (Figure 4.7).

The net benefits from the policy—reflecting the consequences of both the assessment and regulations and the demand and supply responses to them—are expressed as present values (in 2004) of changes in economic surplus accruing to different groups. Over the 50-year horizon, these net benefits include $75.3 million to domestic producers and $115.9 million to domestic consumers, yielding a total national net benefit of $191.3 million.[26] From a global perspective, the U.S. net benefits are slightly offset by net losses in foreigner surplus (the "consumer surplus" measured off the demand for U.S. exports) worth $32.6 million, leaving global net benefits with a present value in 2004 equal to $158.7 million.[27]

We also estimated the total cost of the policy (in terms of expenditures incurred by processors in compliance), which has a present value in 2004 of $32.7 million. The initial incidence of this cost is on processors, but the incidence is redistributed over time through supply and demand responses. To evaluate the incidence of the compliance cost, we ran a simulation of the costs alone. Column 2 in Table 4.2 shows the impact of the imposition of a compliance cost of 0.525 cents per pound at the processing stage without any other impacts of the marketing order. In present-value terms, the global cost of $31.7 million is lower than the national cost of $35 million because taxing domestic consumption confers a benefit of $4 million to foreign "consumers." Of the total cost, producers pay $7.5 million. Hence, 24 percent of the cost is borne by growers, 76 percent by domestic and foreign consumers combined, and 89 percent by domestic consumers (foreign consumers are net beneficiaries of a tax on domestic consumers).

We applied these same percentages to apportion the incidence of the compliance costs in the context

[25] Note that the policy also marginally reduces the annual standard deviation in prices.

[26] On 78,000 bearing acres in 2001, the producer benefit is worth $2,120 per acre, but the benefits would not be confined to these acres.

[27] The positive effect on export quantity seems to contradict the higher average price and the reduction in foreign "consumer" surplus associated with the policy. The effect on foreign "consumer" surplus is complicated. First, there are some benefits to foreigners from the policy because in the baseline there is a spillover of an aflatoxin event from U.S. demand to foreign demand and the policy-induced reduction in probability and severity of an aflatoxin event applies to export markets as well as domestically. These benefits are offset at least somewhat by larger domestic demand responses, which drive up prices, especially in the early years; in later years, those effects in turn are offset at least somewhat by the consequences of U.S. supply response to the policy. The benefits to foreigners are greater in the earlier years and, given discounting, the net present value is negative even though the average effect on quantity of exports, undiscounted, is slightly positive.

Table 4.2. **Simulation Results and Sensitivity Analysis: Baseline Scenario**

	Baseline 1	Cost Only 2	High Impact 3	Low Impact 4
Consequences of the Marketing Order				
Induced Changes in Average of Annual Values, 2000–2050				
Bearing Area (acres)	1,669.30	−144.80	2,501.90	1,159.00
Production (million lbs)	8.62	−0.75	12.97	5.97
U.S. Consumption (million lbs)	9.92	−1.12	14.76	6.87
Exports (million lbs)	−1.25	0.37	−1.73	−0.87
Stocks (million lbs)	−1.30	0.18	−1.98	−0.86
New Plantings (acres)	125.70	−10.00	186.10	91.40
Induced Changes in Final Values in 2050				
Bearing Area in 2050 (acres)	3,605.50	−288.10	5,385.40	2,615.40
Stocks in 2050 (million lbs)	−2.31	0.19	−3.31	−1.76
Production in 2050 (million lbs)	25.95	−2.11	38.92	18.64
Domestic Consumption in 2050 (million lbs)	26.47	−2.59	38.69	19.60
Exports in 2050 (million lbs)	0.30	0.50	1.16	−0.14
Consequences over 50-Year Horizon				
Present Values in 2004 in Millions of 2003 Dollars				
Cost of Compliance (CC)	32.67	31.72	31.49	33.66
Changes in U.S. Consumer Surplus (CS)	115.93	−27.45	178.73	75.18
Net Changes in Foreign Surplus (FS)	−32.57	4.00	−48.55	−21.24
Changes in California Producer Surplus (PS)	75.33	−7.54	115.45	48.20
National Benefits (NS = CS + PS)	191.26	−35.04	294.20	123.38
Benefit-Cost Ratios over 50-Year Horizon				
National Benefit-Cost Ratio	5.90	−1.10	9.30	3.70
Grower Share of Costs	0.24	0.24	0.24	0.24
Grower Benefit-Cost Ratio	9.60	−1.00	15.20	6.00
Consequences over 20-Year Horizon				
Present Values in 2004 in Millions of 2003 Dollars				
Cost of Compliance (CC)	13.02	12.67	12.09	13.90
Changes in U.S. Consumer Surplus (CS)	33.76	−10.19	48.97	22.14
Net Changes in Foreign Surplus (FS)	−20.97	2.40	−28.79	−14.40
Changes in California Producer Surplus (PS)	37.99	−4.15	53.22	25.42
National Benefits (NS = CS + PS)	71.76	−14.34	102.19	47.57
Benefit-Cost Ratios over 20-Year Horizon				
National Benefit-Cost Ratio	5.50	−1.10	8.50	3.40
Grower Share of Costs	0.33	0.33	0.33	0.33
Grower Benefit-Cost Ratio	8.90	−1.00	13.50	6.00

Figure 4.4. **Estimated Impact of the Marketing Order on Grower Prices, 2000–2050**

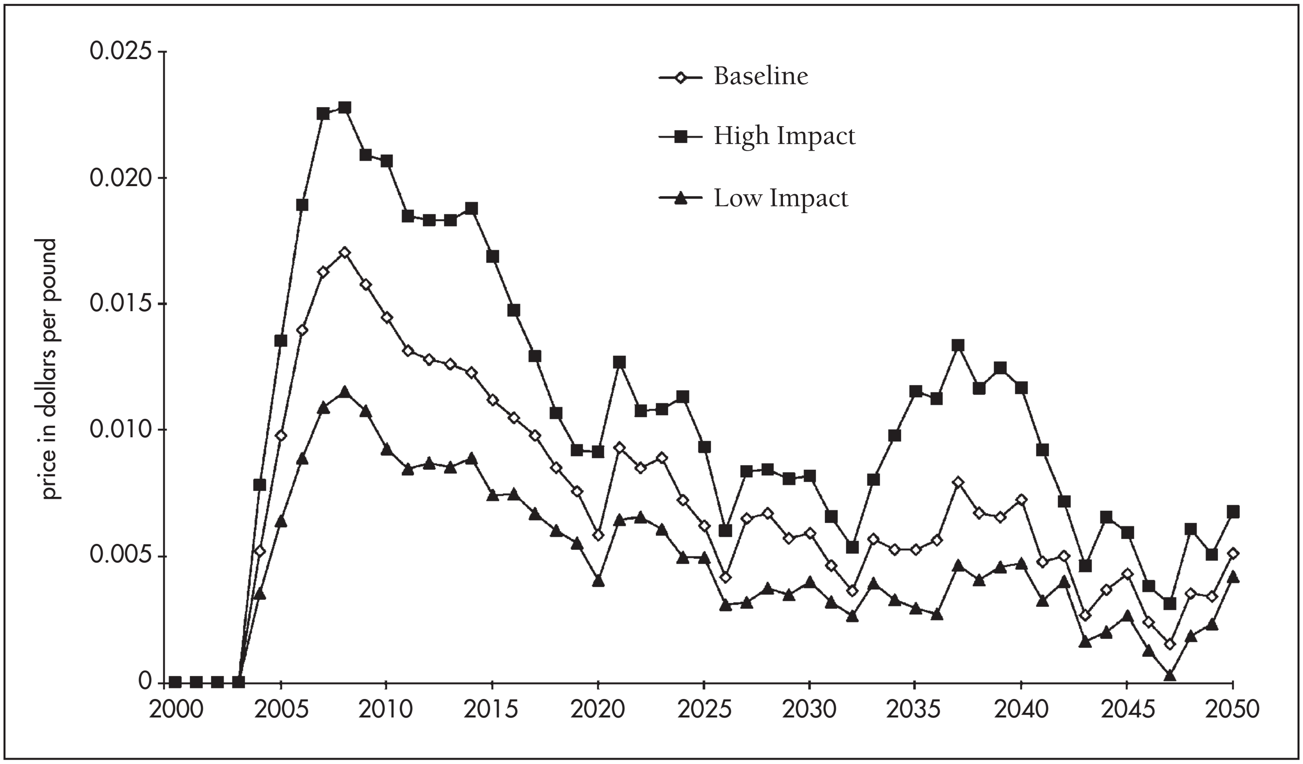


Figure 4.5. **Estimated Impact of the Marketing Order on Net Revenue per Bearing Acre, 2000–2050**

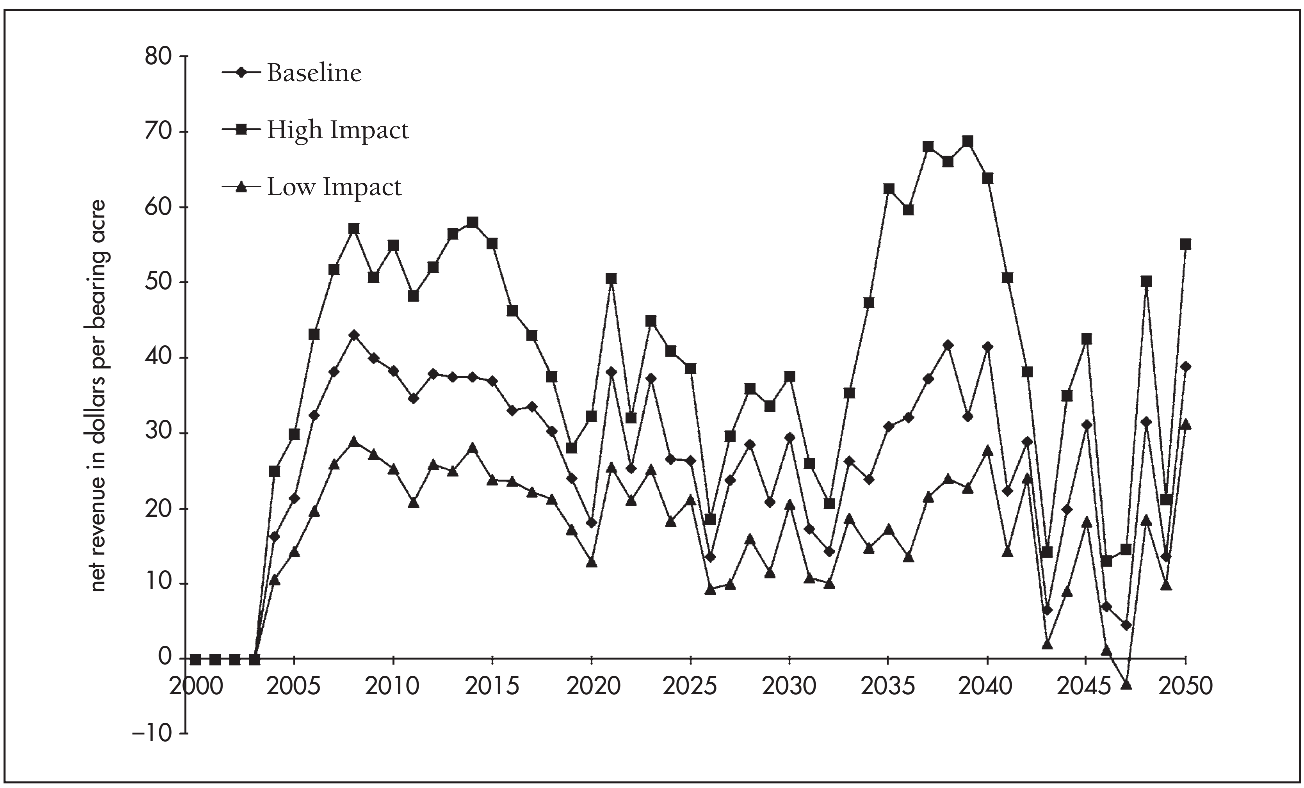


Figure 4.6. **Estimated Impact of the Marketing Order on Bearing Acres, 2000–2050**

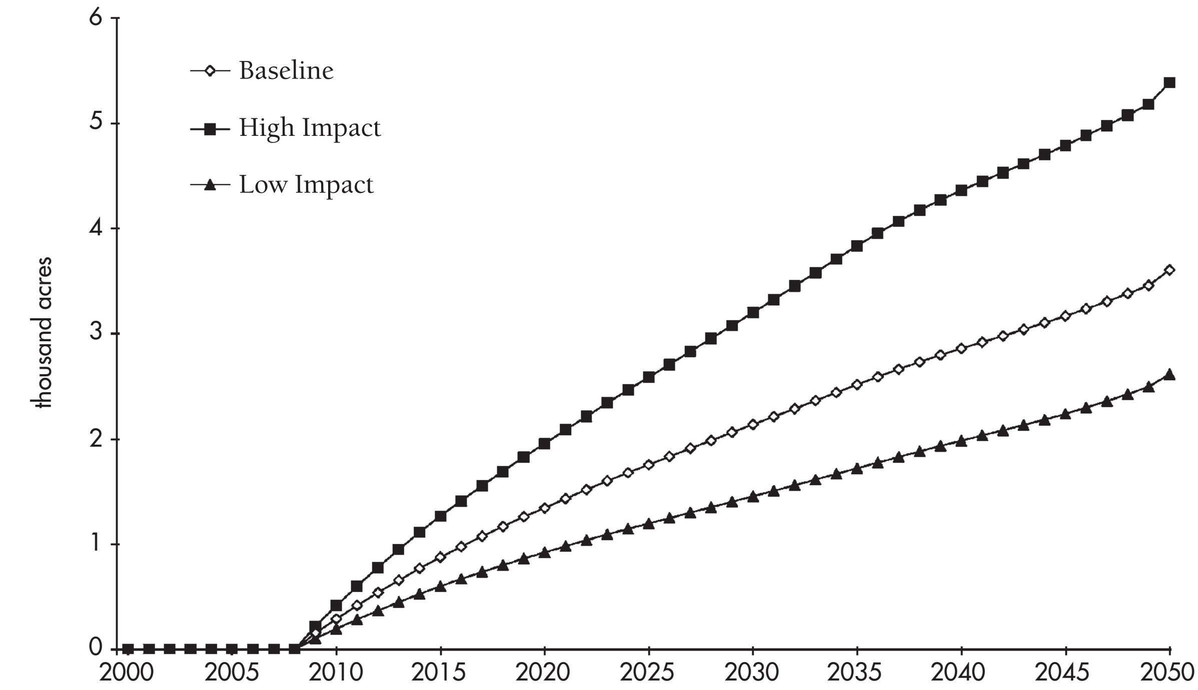
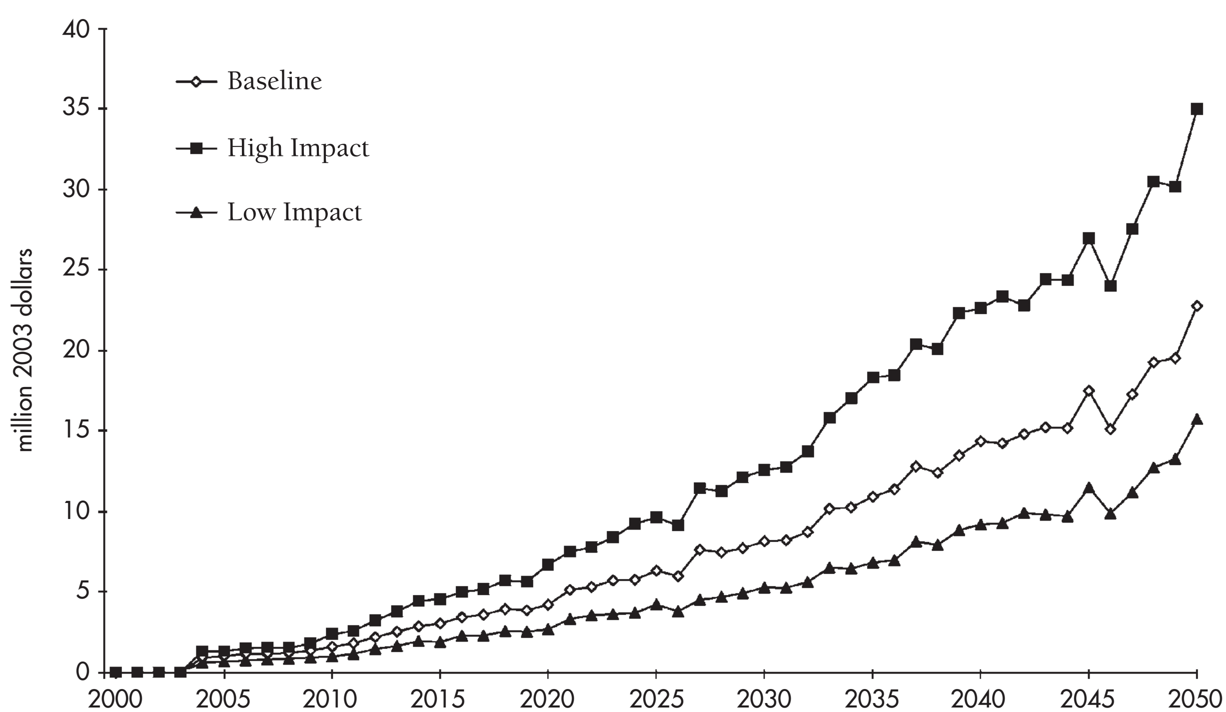


Figure 4.7. **Estimated Impact of the Marketing Order on Consumer Surplus, 2000–2050**



of the marketing order with a range of parameter values. We divided each measure of net benefits by the corresponding measure of the incidence of the costs and computed benefit-cost ratios for domestic producers (9.6), the United States (5.9), and the world (4.9). (Recall that these ratios are the net benefits to the group in question divided by the cost to that group associated with compliance with the marketing order's regulations. Sometimes benefit-cost ratios are defined as gross benefits per dollar of costs, which can be computed by adding 1 to the measures here based on net benefits per dollar of costs.)

In addition to the benefit-cost ratios over the 50-year horizon, we computed benefits and cost ratios over a 20-year horizon using the results from the first 20 years of the 50-year simulation of the industry response to the policy. This was done in response to a suggestion from a reviewer. As can be seen at the bottom of Table 4.2, the benefit-cost ratios over the 20-year horizon—8.9 for California producers and 5.5 for the nation as a whole—are similar to their counterparts over the 50-year horizon. The same was true when we simulated other scenarios and computed benefit-cost ratios over 20 years rather than 50 years. We do not report these details for the other simulations, but they are available.

4.2. Alternative Scenarios

In addition to the baseline, we examined a number of other scenarios with the simulation model. These scenarios indicate how the results of the analysis change under alternative modeling assumptions, illustrating how sensitive the results are to those assumptions. They also provide a number of comparative dynamic results that reveal economic relationships implicit in the model structure.

High-Impact and Low-Impact Scenarios

To examine the general sensitivity of results to modeling assumptions, we devised a "high impact" scenario and a "low impact" scenario, and we report the summary results for those simulations in columns 3 and 4 of Table 4.2. For the high-impact scenario, we alter most of the parameters of the model by 10 percent in the direction that would increase the impact of the policy; for the low-impact scenario, we alter the parameters by 10 percent in the opposite direction. These scenarios reveal how the results are affected by a modest but consistent upward or downward bias in parameter values.

As shown at the bottom of the table, the combined effect of the parameter changes varies the estimated impacts of the marketing order by more than 10 percent. Compared with a benefit-cost ratio for producers of 9.6 in the baseline scenario, the ratio is 15.2 (58 percent higher) in the high-impact scenario and 6.0 (37 percent lower) in the low-impact scenario. Similarly for the United States as a whole, compared with a benefit-cost ratio of 5.9 in the baseline scenario, the ratio is 9.3 (57 percent higher) in the high-impact scenario and 3.7 (37 percent lower) in the low-impact scenario. Nevertheless, the benefit-cost ratios are all well greater than zero, even in the low-impact scenario, indicating that the policy entails substantial net benefits for both producers and for the nation.

Underlying Market Parameters: The Demand Side

Table 4.3 compares estimated impacts in the baseline scenario with those for alternative scenarios in which we allow for different values of underlying elasticities of demand response to prices and demand growth. The alternative values are meant to represent reasonable estimates of upper and lower bounds for the parameters relative to the baseline that represents the most plausible point estimate.

Changing either the domestic or the foreign demand elasticity has an impact on the results. In columns 2 and 3 of Table 4.3, the impacts of changing the domestic demand elasticity can be seen. Halving the domestic demand elasticity from −1.0 to −0.5 increases the estimate of domestic consumer benefits from $115.9 million to $201.5 million and increases the national benefit-cost ratio from 5.9 to 9.0. The same change in demand elasticity reduces the estimate of producer benefits from $75.3 million to $72.3 million but leaves the producers' benefit-cost ratio relatively unaffected (an increase from 9.6 to 9.9) because changing the demand elasticity changes the incidence of the costs as well as the benefits. These impacts are all consistent with a steeper demand curve and a smaller response by consumers to a change in price. Doubling the domestic demand elasticity from −1.0 to −2.0 has an opposite effect of a similar magnitude. The comparatively small changes in the benefit-cost ratios (especially for producers) suggest that the domestic demand elasticity is not a critical parameter for estimating the impact of the marketing order.

Halving and doubling the foreign (export) demand elasticity have greater effects on the benefit-cost ratios. As reported in columns 4 and 5 of Table 4.3, halving the elasticity from −3.3 to −1.65 increases the producers' benefit-cost ratio from 9.6 to 11.6 while doubling the elasticity to −6.6 reduces the benefit-cost ratio from 9.8 to 7.8. Like the domestic demand

Table 4.3. **Implications of Demand Parameters for Consequences of the Marketing Order**

		Domestic Demand Elasticity		Export Demand Elasticity		Low Stock Demand Elasticity	High Demand Growth
	Baseline	***Low***	***High***	***Low***	***High***		
	1	**2**	**3**	**4**	**5**	**6**	**7**
Demand Parameters							
Domestic Demand (DD) Elasticity	−1.0	**−0.5**	**−2.0**	−1.0	−1.0	−1.0	−1.0
Export Demand (ED) Elasticity	−3.3	−3.3	−3.3	**−1.7**	**−6.6**	−3.3	−3.3
Stock Demand (SD) Elasticity	−2.0	−2.0	−2.0	−2.0	−2.0	**−1.0**	−2.0
Demand Growth Rate (percent)	3.6	3.6	3.6	3.6	3.6	3.6	**5.4**
Consequences of the Marketing Order for Prices and Quantities of California Pistachios							
Induced Changes in Average of Annual Values, 2000–2050							
Bearing Area (acres)	1,669.30	1,528.70	1,886.10	1,880.20	1,388.40	1,677.90	2,136.20
Production (million lbs)	8.62	7.87	9.77	9.66	7.21	8.66	11.13
Domestic Consumption (million lbs)	9.92	9.01	11.35	10.03	9.77	9.92	15.54
Exports (million lbs)	−1.25	−1.09	−1.52	−0.32	−2.53	−1.23	−4.26
Stocks (million lbs)	−1.30	−1.26	−1.36	−1.57	−1.00	−0.64	−2.71
New Plantings (acres)	125.67	113.10	145.50	139.20	107.30	126.70	169.00
Benefits and Costs of the Marketing Order over a 50-Year Horizon							
Present Values in 2004 in Millions of 2003 Dollars							
Cost of Compliance (CC)	32.67	30.37	36.68	33.16	31.91	32.56	48.68
Changes in U.S. Consumer Surplus (CS)	115.93	201.50	71.42	111.27	117.69	116.37	147.69
Net Changes in Foreign Surplus (FS)	−32.57	−32.27	−32.84	−34.25	−29.44	−33.01	−47.94
Changes in California Producer Surplus (PS)	75.33	72.25	80.89	92.27	59.98	75.78	109.84
National Benefits (NS = CS + PS)	191.26	273.75	152.32	203.54	177.67	192.15	257.53
Benefit-Cost Ratios							
National Benefit-Cost Ratio	5.90	9.00	4.20	6.10	5.30	5.90	5.30
Grower Share of Costs	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Grower Benefit-Cost Ratio	9.60	9.90	9.20	11.60	7.80	9.70	9.40

elasticity, this parameter is not critical to the overall efficacy of the marketing order.

Storage plays an important role in smoothing out year-to-year variations in price. In the baseline scenario, we model a stock demand parameterized with the average 1997–2001 stock level and a demand elasticity of −2 and we assume that the demand for stocks grows over time at the same rate as domestic and export demand, 3.6 percent per year. A scenario where the elasticity of demand for stocks is halved to −1.0 is reported in column 6 of Table 4.3. This parameter change has virtually no effect on the estimated impacts of the marketing order.

In the base scenario, it was assumed that domestic, foreign, and stock demand would all grow at 3.6 percent per year. In the scenario reported in column 7 of Table 4.3, the underlying growth rate in demand is increased by 50 percent of the baseline to 5.4 percent per year. The result is a much larger industry over time with correspondingly greater benefits and costs from the marketing order. Producer benefits increase by about 45 percent over the baseline and national

Table 4.4. **Implications of Compliance Costs and Probability of an Aflatoxin Event**

	Baseline	Compliance Cost		Probability of an Aflatoxin Event		
		High	*Low*	*Low*	*Zero*	*High*
	1	2	3	4	5	6
Impact Parameters						
Aflatoxin Case Probability						
without Marketing Order (percent)	4.0	4.0	4.0	**2.0**	**0.0**	**8.0**
with Marketing Order (percent)	2.0	2.0	2.0	**1.0**	**0.0**	**4.0**
Compliance Costs (cents per lb)	0.525	**0.788**	**0.350**	0.525	0.525	0.525
Consequences of the Marketing Order for Prices and Quantities of California Pistachios						
Induced Changes in Average of Annual Values, 2000–2050						
Bearing Area (acres)	1,669.31	1,595.10	1,718.80	911.40	135.40	3,020.50
Production (million lbs)	8.62	8.24	8.88	4.68	0.70	15.63
Domestic Consumption (million lbs)	9.92	9.34	10.30	5.42	1.05	17.85
Exports (million lbs)	−1.25	−1.06	−1.38	−0.71	−0.35	−2.12
Stocks (million lbs)	−1.30	−1.23	−1.34	−0.67	−0.13	−2.37
New Plantings (acres)	125.67	120.50	129.10	73.70	9.40	229.50
Benefits and Costs of the Marketing Order over a 50-Year Horizon						
Present Values in 2004 in Millions of 2003 Dollars						
Cost of Compliance (CC)	32.67	48.93	21.80	32.78	32.92	32.43
Changes in U.S. Consumer Surplus (CS)	115.93	101.86	125.32	70.83	25.60	193.78
Net Changes in Foreign Surplus (FS)	−32.57	−30.55	−33.92	−17.48	−3.68	−55.76
Changes in California Producer Surplus (PS)	75.33	71.37	77.67	39.78	7.12	132.08
National Benefits (NS = CS + PS)	191.26	173.23	203.28	110.60	32.72	325.86
Benefit–Cost Ratios						
National Benefit-Cost Ratio	5.90	3.50	9.30	3.40	1.00	10.00
Grower Share of Costs	0.24	0.24	0.24	0.24	0.24	0.24
Grower Benefit-Cost Ratio	9.60	6.10	14.90	5.10	0.90	17.00

benefits increase by 35 percent, but the effect on the producers' benefit-cost ratio is small (a decrease from 9.6 to 9.4) and the effects on the national benefit-cost ratio are modest (a decrease from 5.9 to 5.3). Hence, although this parameter has important long-term implications for the size of the industry and the total benefits and costs of the marketing order, it has little impact on the viability of the marketing order.

Parameters Defining Marketing-Order Impacts

Tables 4.4 and 4.5 compare estimated impacts in the baseline scenario with those for alternative scenarios in which we allow for different values of the parameters that define the impacts of the marketing order on supply and demand—measures of costs of inspection and compliance, probability of an aflatoxin event, demand shocks associated with an event, and demand changes in response to greater consumer confidence in the product as a result of certification. The alternative values are meant to represent reasonable estimates of upper and lower bounds compared with the baseline, which represents the most plausible point estimate, and the wide range of values for some of these parameters reflects our comparative uncertainty about these numbers relative to the underlying market parameters previously discussed.

Inspection and compliance costs can have a large impact on the benefit-cost ratio under the marketing order. A scenario where these costs are increased by half of the baseline value of 0.525 cents per pound is shown in column 2 of Table 4.4. The main effect of increasing the unit costs by 50 percent is an increase in the total costs of compliance by 50 percent, from $33 million to $48.9 million—an increase of $15.9 million. Hence, national benefits are lower by $20 million and producer benefits are lower by $4 million, reflecting the differential incidence of the costs of compliance. In turn, there are implications for the demand and supply responses to the policy, which are slightly muted relative to the baseline. Hence, the benefit-cost ratios are affected differentially. The effect on the producers' benefit-cost ratio is reasonably large (a decrease by more than one-third from 9.6 to 6.1) and the effects on the national benefit-cost ratio are comparable (a decrease by more than one-third from 5.9 to 3.5). Analogous but opposite patterns are revealed when we simulate a reduction in compliance costs of the same magnitude. The range of benefit-cost ratios suggests that inspection and compliance costs are an important factor in the assessment of the marketing order. Fortunately, because the protocol of testing is defined within the marketing order and the industry has experience with testing for foreign markets, these costs can be estimated with reasonable accuracy and the baseline estimates can therefore be taken with reasonable confidence.

In the baseline case, a primary source of benefits from the marketing order is through a reduction in the probability of an aflatoxin event. The probability of an event with and without the marketing order is among the most difficult parameters to estimate given the lack of historical experience or other data. The results of three scenarios dealing with this parameter are reported in columns 4 through 6 of Table 4.4. In the baseline scenario, we assumed the annual probability of an event would be 4 percent without a marketing order and 2 percent with a marketing order. In the "low probability" scenario reported in column 6, these two probabilities are both halved—to 2 percent and 1 percent, respectively. In the "high probability" scenario reported in column 6, these two probabilities are both doubled—to 8 percent and 4 percent, respectively. And in the "zero probability" scenario reported in column 5, these two probabilities are both set equal to zero—representing a world in which there is no real risk of an aflatoxin event and the only impact of the marketing order on demand is from certification, which causes a permanent increase in demand.

First, consider the zero-probability scenario described in column 5. In this case, the increase in domestic demand facing producers in response to certification (1 cent per pound) is almost twice as large as the demand-decreasing effect of the cost of certification (0.525 cents per pound) and the consequences follow straightforwardly from that fact. The producer, national, and global benefit-cost ratios are all similar, about 0.9, because the present value of gross benefits in each case is not quite twice the present value of costs. This element of the overall benefit-cost picture is a constant component of all the scenarios in which we allow for domestic demand enhancement associated with certification.

In the low-probability scenario described in column 4 of Table 4.4, there are additional benefits when the probability of an aflatoxin event is 2 percent without a marketing order and is reduced to 1 percent by the order. Producers receive a net benefit of $7.1 million from certification (column 5) and a further $32.7 million from the reduced impacts of aflatoxin events on demand, both domestically and in export markets, such that their total benefit is $39.8 million. Consequently, the producers' benefit-cost ratio is 5.1 (in the low-probability scenario) rather than 0.9 (in the zero-probability scenario), both of which are much lower than that of the baseline scenario (9.6). Similarly, the national benefit-cost ratio is much greater in the baseline scenario (5.9) than in the low-probability scenario (3.4) or the zero-probability scenario (1.0). The opposite pattern of effects can be seen when comparing the results in the high-probability scenario in column 6 with those in the baseline, low-probability, and zero-probability scenarios. The total benefits and the benefit-cost ratios are very sensitive to changes in the probability of an aflatoxin event when the introduction of a marketing order reduces that probability by one-half.

Table 4.5 reports the results of sensitivity analysis with respect to other parameters that define the market

Table 4.5. Implications of Other Parameters for Consequences of the Marketing Order

	Baseline	Foreign Demand Impact		Zero Impact of Quality Assurance
		Zero	*Large*	
	1	2	3	4
Impact Parameters				
Foreign Demand/Domestic Shock (percent)	21.50	**0.00**	**43.00**	21.50
Domestic Demand Enhancement (dollars per lb)	0.01	0.01	0.01	**0.00**
Planting Elasticity (percent)	2.00	2.00	2.00	2.00
Consequences of the Marketing Order for Prices and Quantities of California Pistachios				
Induced Changes in Average of Annual Values, 2000–2050				
Bearing Area (acres)	1,669.31	1,366.00	1,990.70	1,386.50
Production (million lbs)	8.62	7.05	10.28	7.16
Domestic Consumption (million lbs)	9.92	10.03	9.79	7.72
Exports (million lbs)	−1.25	−2.94	0.54	−0.52
Stocks (million lbs)	−1.30	−1.09	−1.51	−1.03
New Plantings (acres)	125.67	101.70	151.10	106.10
Benefits and Costs of the Marketing Order over a 50-Year Horizon				
Present Values in 2004 in Millions of 2003 Dollars				
Cost of Compliance (CC)	32.67	32.66	32.68	32.48
Changes in U.S. Consumer Surplus (CS)	115.93	121.00	110.33	62.46
Net Changes in Foreign Surplus (FS)	−32.57	−37.46	−27.11	−24.85
Changes in California Producer Surplus (PS)	75.33	62.89	88.57	60.29
National Benefits (NS = CS + PS)	191.26	183.89	198.90	122.75
Benefit–Cost Ratios				
National Benefit-Cost Ratio	5.90	5.60	6.10	3.80
Grower Share of Costs	0.24	0.24	0.24	0.24
Grower Benefit-Cost Ratio	9.60	8.00	11.30	7.80

response to an aflatoxin event and the marketing order. Columns 2 and 3 of Table 4.5 represent scenarios in which the spillover effects of a U.S. aflatoxin event on foreign demand are reduced to zero (rather than 21.5 percent of the U.S. shock as defined in the baseline scenario) or doubled from the baseline to 43 percent of the U.S. demand shock. Eliminating the spillover effect of an aflatoxin event means that the benefits from the marketing order, which mitigated those effects, are commensurately reduced. Hence, most of the effects on quantities and prices are smaller in column 2 relative to the baseline in column 1 (or column 3) (the exception is the effect on exports, which is a larger negative effect). The producer benefits are smaller but the losses in foreign consumer surplus and the gains in domestic consumer surplus are larger. The national benefit-cost ratio is somewhat smaller than in the baseline and the grower benefit-cost ratio is somewhat smaller as well, reduced from 9.6 to 8.0. Doubling the importance of spillover effects has opposite effects on the results, as can be seen by comparing the measures in column 3 with the baseline in column 1. Notably, the effects of the marketing order on exports are now positive (the effect on exports is negative in all but three scenarios) and the losses in foreign consumer surplus are smaller, as are the gains in domestic consumer surplus. While the numbers are affected, this aspect of the model specification does not seem to have important implications for conclusions regarding the impact of the marketing order.

In the baseline scenario, we assumed that domestic consumers would be willing to pay 1 cent per pound more for pistachios with USDA inspection because of the certification and labeling aspects. A scenario excluding this effect is used to assess the importance of the labeling impact for the results, and the results in that scenario are shown in column 4 of Table 4.5. Compared to the baseline, producer benefits are reduced by $15 million (from $75.3 million to $60.3 million) and domestic consumer benefits are reduced by $53.7 million (from $115.9 million to $62.5 million). Hence, national benefits are reduced by about $69 million (from $191.3 million to $122.8 million) and global benefits are reduced by $60.8 million. These figures indicate that certification and labeling could represent a substantial share of the total benefits and that the overall estimate could be sensitive to assumptions about this aspect. We assume an increase in willingness-to-pay of 1 cent per pound (close to 1 percent of the producer price), which seems very modest but is nevertheless a speculative estimate. The estimates of benefits associated with this effect could be interpreted as representing the consequences for each cent of increased willingness-to-pay over a range of up to a few cents per pound. In addition, we note that the benefit-cost ratios remain favorable even when we assume that there is no effect of certification and labeling *per se* on demand.

Finally, we conducted a further set of simulations to evaluate the implications of the end-period assumptions (recall that in the plantings model we projected the annual flows of net revenue per acre in 2050 forward for 2051 through 2100). To consider the robustness of the results, we scaled this stream of revenue per acre up by 20 percent and down by 20 percent and we report the results relative to the baseline case in Table 4.6. These results show that different valuations of the stream of revenue from 2050 forward have some effect on plantings (and hence production, prices, and so on), especially in later years, but with only minor consequences for the average values of these variables within the period 2000–2050. The benefit-cost ratios are not affected.

Table 4.6. Implications of End-Time Valuation for Simulated Values

	Baseline	20 Percent Higher Revenue per Acre 2051–2100	20 Percent Lower Revenue per Acre 2051–2100
Induced Changes in Average Annual Values for California Pistachios, 2000–2050			
Bearing Area (acres)	1,669.30	1,706.20	1,619.40
Production (million lbs)	8.62	8.81	8.37
U.S. Consumption (million lbs)	9.92	10.01	9.78
Exports (million lbs)	−1.25	−1.16	−1.37
Stocks (million lbs)	−1.30	−1.27	−1.32
New Plantings (acres)	125.70	132.60	117.70
Induced Changes in Final Values for California Pistachios in 2050			
Bearing Area in 2050 (acres)	3,605.50	3,803.90	3,381.60
Stocks in 2050 (million lbs)	−2.31	−2.21	−2.40
Production in 2050 (million lbs)	25.95	27.23	24.50
Domestic Consumption in 2050 (million lbs)	26.47	27.22	25.61
Exports in 2050 (million lbs)	0.29	0.84	−0.31
Consequences over 50-Year Horizon			
Present Values in 2004 in Millions of 2003 Dollars			
Cost of Compliance (CC)	32.67	32.80	32.43
Changes in U.S. Consumer Surplus (CS)	115.93	117.60	113.38
Net Changes in Foreign Surplus (FS)	−32.57	−32.03	−32.99
Changes in California Producer Surplus (PS)	75.33	74.70	75.70
National Benefits (NS = CS + PS)	191.25	192.30	189.09
Benefit–Cost Ratios over 50-Year Horizon			
National Benefit-Cost Ratio	5.90	5.90	5.80
Grower Share of Costs	0.24	0.24	0.24
Grower Benefit-Cost Ratio	9.60	9.60	9.60
Consequences over 20-Year Horizon			
Present Values in 2004 in Millions of 2003 Dollars			
Cost of Compliance (CC)	13.02	13.00	12.98
Changes in U.S. Consumer Surplus (CS)	33.76	33.62	33.44
Net Changes in Foreign Surplus (FS)	−20.97	−20.89	−20.92
Changes in California Producer Surplus (PS)	37.99	37.89	37.91
National Benefits (NS = CS + PS)	71.76	71.50	71.35
Benefit–Cost Ratios over 20-Year Horizon			
National Benefit-Cost Ratio	5.50	5.50	5.50
Grower Share of Costs	0.33	0.33	0.33
Grower Benefit-Cost Ratio	8.90	8.90	8.90

5. CONCLUSION

An aflatoxin event could impose serious costs on the California pistachio industry. The proposed marketing order is intended to reduce the odds of an event, mitigate the consequences if an event should occur, and provide some quality assurance to buyers to offset the negative consequences of concerns over the potential for a food scare affecting pistachios. In this study, we have modeled the market for California pistachios to provide an *ex ante* assessment of the benefits and costs and other consequences of the proposed marketing order looking forward 50 years from its introduction. Our approach used a stochastic dynamic simulation of the industry under scenarios with and without the marketing order to compare the stream of simulated outcomes and the consequences for measures of economic welfare of producers in the industry, consumers, the nation as a whole, and the world.

To assess the implications of the marketing order required incorporating into the simulation a number of parameters representing the odds of an aflatoxin event, its consequences for demand, and the extent to which a marketing order would reduce those magnitudes. Many of these parameters are hard to estimate because relevant historical data are not available for pistachios and it is hard to extrapolate from the information that is available with any precision or confidence. As well as simulating the consequences implied by "best guess" values for key parameters, we undertook extensive sensitivity analysis to evaluate the importance of particular assumptions about parameters.

Across the full range of parameters used in the analysis, the benefit-cost analysis was always favorable to the policy: the measured benefits to producers, the nation, and the world always well exceeded the corresponding measure of costs, typically by many times. The benefit-cost ratios were generally greater than 3:1 and often greater than 6:1, which means there is substantial leeway to accommodate potential errors in assumptions and yet have favorable findings. In present-value terms, the benefits to producers were estimated in the baseline scenario at $75.3 million. Domestic consumers would gain $115.9 million, 60 percent of the overall benefits. These are significant values and are large relative to the cost of compliance with the program, which is a very small amount—about one-half of 1 percent of the current value of domestic sales.

This study revealed a number of issues that may be important in analyses of other policies in the context of perennial crops and in analyses of food safety and quality assurance policies in a more general setting. First, analyses of food safety and food scares deal with events that occur with a very low frequency (or low probability) that is difficult to estimate with any precision and that, when they do occur, can have disastrous consequences for demand. The modeling of low-probability catastrophic events might not be well represented by the use of simple comparative statics and averages; hence our use of an explicit stochastic dynamic simulation. Second, in the case of perennial crops, analysis becomes particularly complicated because the initial impacts of the policies on demand precede by many years the induced supply response. The dynamic path of costs and benefits and their changing incidence over time are critical elements of the story. These elements are difficult to model but might be pivotal determinants of the economics of the policy.

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APPENDIX
DATA TABLES

Table A1. World Pistachio Production by Producing Country for 1980–2003 in Millions of Pounds

Year	Iran[a]	Iran[b]	U.S.	Turkey	Syria	Greece	Italy	Total World[c]
1980	55.0	NA	27.2	15.4	11.0	5.6	0.4	114.6
1981	92.4	NA	14.4	46.2	20.2	5.0	9.8	188.0
1982	50.6	NA	43.9	24.2	17.6	3.6	0.4	140.3
1983	132.0	NA	26.3	39.6	20.2	5.6	8.8	232.5
1984	154.0	NA	63.0	33.0	23.8	4.4	0.4	278.6
1985	140.0	NA	27.1	72.6	22.0	5.0	4.4	271.1
1986	130.0	NA	76.7	44.0	31.4	5.0	0.6	287.7
1987	70.0	NA	33.0	55.0	27.6	8.8	8.8	203.2
1988	180.0	187.4	93.4	33.0	39.4	6.6	0.6	353.0
1989	70.0	88.2	38.8	77.2	34.8	10.8	7.2	238.8
1990	200.0	209.4	119.8	30.8	44.0	5.8	0.6	401.0
1991	401.2	99.2	76.3	99.2	24.0	5.0	6.6	612.3
1992	445.3	242.5	146.5	44.0	44.0	10.0	0.6	690.4
1993	504.9	220.5	150.9	110.0	48.4	9.0	8.8	832.0
1994	429.9	143.3	128.3	55.1	52.9	9.3	0.7	676.2
1995	518.1	264.6	147.7	66.1	35.3	8.8	4.9	780.9
1996	175.0	NA	104.3	88.2	39.7	9.6	0.7	417.5
1997	150.0	100.0	179.5	88.1	33.1	11.0	8.8	470.5
1998	375.0	NA	187.5	55.1	79.4	11.0	1.1	709.1
1999	289.2	154.0	122.4	88.0	66.3	11.0	5.8	582.7
2000	264.6	396.8	241.6	132.3	68.3	14.3	0.2	721.3
2001	253.5	154.3	160.3	77.2	88.0	14.3	0.2	593.5
2002	661.0	396.8	302.4	88.2	86.4	18.7	5.5	1,162.2
2003	683.0	330.7	118.0	110.2	110.2	18.7	5.5	1,045.6

[a] Source: Iran's Ministry of Agriculture (not verifiable).
[b] Source: Rafsanjan Pistachio Producers Cooperative (RPPC) (not verifiable).
[c] World total includes Iran's production as given by Iran's Ministry of Agriculture.
Source: USDA; California Pistachio Commission.

Table A2. **California Pistachios – Bearing, Nonbearing, Total, and New-Planting Acres and Yield per Bearing Acre, 1980–2003**

Year	Bearing Acres	Nonbearing Acres	Total Acres	New-Planting Acres	Yield in Pounds per Acre
1980	25,773	8,989	34,762	1,382	1,055
1981	27,541	13,084	40,625	6,377	523
1982	29,902	15,619	45,521	5,478	1,468
1983	31,143	15,959	47,102	4,183	844
1984	30,788	16,794	47,582	2,506	2,027
1985	32,332	18,739	51,071	5,013	838
1986	34,243	20,438	54,681	2,299	2,187
1987	40,985	16,365	57,350	1,265	818
1988	47,234	10,258	57,492	1,533	2,117
1989	50,900	12,000	62,900	3,062	800
1990	53,700	11,100	64,800	2,687	2,375
1991	55,700	13,300	69,000	3,508	1,465
1992	56,500	13,900	70,400	2,902	2,592
1993	57,000	15,700	72,700	2,639	2,648
1994	57,507	16,633	74,140	3,514	2,232
1995	60,300	13,400	73,700	3,397	2,449
1996	64,300	17,100	81,400	4,209	1,622
1997	65,373	17,062	82,435	3,303	2,746
1998	68,000	19,300	87,300	3,620	2,757
1999	71,000	21,000	92,000	5,496	1,724
2000	74,578	21,730	96,307	3,903	3,239
2001	78,000	23,500	101,500	5,151	2,055
2002	83,000	23,000	106,000	1,593	3,644
2003	88,000	23,000	111,000	658	1,341

Source: California Agricultural Statistics Service; California Pistachio Commission.

Table A3. **Production and Quality of California Pistachios, 1980–2003**

Year	Total Production (million lbs)	Open In-Shell		Closed Shell		Shelling Stock	
		Production (million lbs)	Percent of Total	Production (million lbs)	Percent of Total	Production (million lbs)	Percent of Total
1980	27.2	18.6	68.4	–	–	8.6	31.6
1981	14.1	10.9	77.1	–	–	3.2	22.9
1982	43.2	37.4	86.5	–	–	5.8	13.5
1983	26.3	20.9	79.4	–	–	5.4	20.6
1984	62.6	45.2	72.1	–	–	17.5	27.9
1985	27.3	22.5	82.4	–	–	4.8	17.6
1986	76.7	64.5	84.1	–	–	12.2	15.9
1987	33.5	29.2	87.1	–	–	4.3	12.9
1988	96.4	72.0	74.7	–	–	24.4	25.3
1989	39.5	33.2	84.0	–	–	6.3	16.0
1990	117.3	92.7	79.0	–	–	24.6	21.0
1991	76.4	58.9	77.1	–	–	17.5	22.9
1992	146.5	114.3	78.0	–	–	32.2	22.0
1993	150.9	112.6	74.7	–	–	38.3	25.3
1994	128.3	94.1	73.3	–	–	34.3	26.7
1995	147.7	107.3	72.7	–	–	40.3	27.3
1996	104.3	84.5	81.0	–	–	19.9	19.0
1997	179.5	136.6	76.1	–	–	42.9	23.9
1998	187.5	137.6	73.4	38.6	20.6	11.2	6.0
1999	122.4	104.4	85.3	12.0	9.8	6.0	4.9
2000	241.6	188.8	78.2	38.6	16.0	14.1	5.8
2001	160.3	125.8	78.5	26.4	16.4	8.1	5.1
2002	302.4	241.7	79.9	42.1	13.9	18.7	6.2
2003	118.0	89.2	75.6	22.1	18.7	6.7	5.7

Source: California Agricultural Statistics Service; California Pistachio Commission processor producer delivery reports.

Table A4. **Quantity, Price, and Value of California Pistachios, 1980–2003**

Year	Production (million pounds)	Average Return (dollars per pound)	Total Value (million dollars)	Value per Bearing Acre (dollars per acre)
1980	27.2	2.05	55.80	2,165
1981	14.4	1.36	19.60	712
1982	43.9	1.49	63.70	2,130
1983	26.3	1.41	37.30	1,198
1984	63.0	0.98	61.70	2,004
1985	27.1	1.37	36.60	1,132
1986	76.7	1.12	85.90	2,509
1987	33.0	1.37	47.20	1,152
1988	93.4	1.22	109.30	2,314
1989	38.8	1.63	63.20	1,242
1990	119.9	1.02	129.50	2,412
1991	76.3	1.25	100.70	1,808
1992	146.5	1.03	150.90	2,671
1993	150.9	1.07	161.50	2,833
1994	128.3	0.92	118.10	2,054
1995	147.7	1.09	160.94	2,669
1996	104.3	1.16	120.99	1,882
1997	179.5	1.13	202.84	3,103
1998	187.5	1.03	193.10	2,840
1999	122.4	1.33	162.78	2,293
2000	241.6	1.01	239.18	3,207
2001	160.3	1.01	166.71	2,137
2002	302.4	1.11	335.66	4,044
2003	118.0	1.15	135.70	1,542

Source: California Agricultural Statistics Service; California Pistachio Commission.

Table A5. Production, Quantity, and Price of California Pistachios and Almonds, 1980–2003

	Almonds		Pistachios	
	Price (dollars per pound)	Production (million pounds)	Price (dollars per pound)	Production (million pounds)
1980	$1.47	322	$2.05	27
1981	$0.78	408	$1.36	14
1982	$0.94	347	$1.49	44
1983	$1.04	242	$1.41	26
1984	$0.77	590	$0.98	63
1985	$0.80	465	$1.37	27
1986	$1.92	250	$1.12	77
1987	$1.00	660	$1.37	33
1988	$1.05	590	$1.22	93
1989	$1.02	490	$1.63	39
1990	$0.93	660	$1.02	120
1991	$1.19	490	$1.25	76
1992	$1.30	548	$1.03	147
1993	$1.94	490	$1.07	151
1994	$1.34	735	$0.92	128
1995	$2.48	370	$1.09	148
1996	$2.08	510	$1.16	104
1997	$1.56	759	$1.13	180
1998	$1.41	520	$1.03	188
1999	$0.86	833	$1.33	122
2000	$0.97	703	$1.01	242
2001	$0.91	830	$1.01	160
2002	$1.11	1,090	$1.11	302
2003	$1.42	1,040	$1.15	118

Source: California Agricultural Statistics Service; California Pistachio Commission; USDA, National Agricultural Statistics Service.

Table A6. Allocation of California Pistachios among Markets for 1980/81–2003/04[a] in Thousands of Pounds

Season[b]	Utilized Production	Loss and Exempt[c]	Marketable Production[d]	Imports[e]	Beginning Stocks[d]	Total Supply[f]	Ending Stocks[d]	Exports[e]
1980/81	11,675	–	11,672	1,175	5,000	17,847	5,135	1,840
1981/82	5,887	–	5,888	1,817	5,135	12,840	2,061	1,480
1982/83	16,984	–	16,986	2,819	2,061	21,866	6,581	3,247
1983/84	11,114	–	11,115	6,683	6,581	24,378	4,977	1,815
1984/85	27,512	–	27,507	7,284	4,977	39,768	11,256	2,758
1985/86	11,518	–	11,518	14,875	11,256	37,649	7,362	1,658
1986/87	31,009	–	31,005	5,357	7,362	43,724	15,005	2,183
1987/88	14,597	18	14,579	2,166	15,005	31,750	5,487	3,469
1988/89	45,684	932	44,752	854	5,487	51,093	14,897	6,442
1989/90	18,213	184	18,029	2,124	14,897	35,051	10,045	5,519
1990/91	42,047	0	42,047	853	10,045	52,945	16,864	8,682
1991/92	25,667	190	25,476	250	16,864	42,590	6,072	15,413
1992/93	65,585	223	65,362	396	6,072	71,830	17,595	27,763
1993/94	62,359	448	61,911	494	17,595	80,000	25,672	21,066
1994/95	51,375	125	51,250	732	25,672	77,654	16,825	25,275
1995/96	64,681	5,177	59,504	422	16,825	76,751	13,795	31,540
1996/97	40,425	0	40,425	944	13,795	55,163	7,696	32,202
1997/98	74,930	0	74,930	417	7,696	83,043	9,742	36,150
1998/99	78,208	0	78,208	549	9,742	88,499	21,264	25,793
1999/00	58,083	0	58,083	262	21,264	79,608	10,462	19,803
2000/01	114,164	0	114,164	920	10,462	125,547	33,329	32,641
2001/02	80,733	0	80,733	532	33,329	114,594	12,425	44,744
2002/03	149,513	0	149,513	764	12,425	162,702	56,180	44,449
2003/04[g]	57,448	0	57,448	1,287	58,180	114,915	23,384	34,999

[a] The conversion factor from in-shell to shelled basis varies year to year for production, stocks, and exports and was 0.39 in 1996/97, 0.42 in 1997/98 and 1998/99, 0.47 in 1999/00 and 2000/01, 0.49 in 2001/02, and 0.48 in 2002/03. For imports, the conversion factor was a constant 0.40.

[b] Season beginning September 1.

[c] Inedibles and noncommercial usage.

[d] California Pistachio Commission.

[e] Bureau of Census, U.S. Department of Commerce.

[f] Marketable production plus imports and beginning stocks.

[g] Preliminary estimates.

Source: USDA, Economic Research Service.

Table A7. **Validation of Storage Model: Average Values from Baseline Simulation**

	Change in Stocks (million lbs)	Stock Trading Profit[a] (million 2003 $)	Value of Production (million 2003 $)	Trading Profit as a Share of Value of Production (percent)		Stocks/ Production (percent)
	$(S_t - S_{t-1})$	(π_t)	(V_t)	$(100 \times \pi_t / V_t)$	$(100 \times \lvert\pi_t\rvert / V_t)$	$(100 \times S_t / Q_t)$
2000	1.38	−1.67	231.80	−0.72	0.72	24.18
2001	−0.68	0.83	231.91	0.36	0.36	24.39
2002	4.28	−5.19	252.65	−2.05	2.05	23.86
2003	0.43	−0.52	253.72	−0.20	0.20	24.28
2004	2.35	−2.84	266.61	−1.07	1.07	24.06
2005	1.46	−1.77	273.48	−0.65	0.65	24.20
2006	2.72	−3.30	286.27	−1.15	1.15	24.12
2007	5.30	−6.42	306.10	−2.10	2.10	23.99
2008	3.36	−4.07	316.80	−1.29	1.29	24.21
2009	2.89	−3.51	328.51	−1.07	1.07	24.27
2010	3.49	−4.23	342.76	−1.24	1.24	24.26
2011	2.10	−2.54	352.15	−0.72	0.72	24.39
2012	4.40	−5.33	370.00	−1.44	1.44	24.28
2013	3.66	−4.44	383.28	−1.16	1.16	24.39
2014	5.70	−6.90	403.93	−1.71	1.71	24.28
2015	4.22	−5.11	419.02	−1.22	1.22	24.35
2016	7.25	−8.78	442.01	−1.99	1.99	24.25
2017	1.61	−1.95	449.33	−0.43	0.43	24.56
2018	9.96	−12.06	482.00	−2.50	2.50	24.15
2019	−2.53	3.06	478.33	0.64	0.64	24.76
2020	11.31	−13.70	519.28	−2.64	2.64	24.10
2021	−1.96	2.37	515.38	0.46	0.46	24.77
2022	12.85	−15.57	558.64	−2.79	2.79	24.14
2023	4.85	−5.87	570.19	−1.03	1.03	24.51
2024	7.18	−8.70	595.39	−1.46	1.46	24.41
2025	11.76	−14.25	624.02	−2.28	2.28	24.34
2026	1.92	−2.32	635.58	−0.37	0.37	24.65
2027	14.48	−17.54	674.73	−2.60	2.60	24.26
2028	1.52	−1.84	684.72	−0.27	0.27	24.68
2029	9.41	−11.40	717.69	−1.59	1.59	24.45
2030	5.13	−6.22	739.28	−0.84	0.84	24.57
2031	8.05	−9.76	769.89	−1.27	1.27	24.46
2032	13.55	−16.41	803.81	−2.04	2.04	24.35
2033	11.62	−14.08	829.82	−1.70	1.70	24.46
2034	9.66	−11.70	857.99	−1.36	1.36	24.52
2035	10.64	−12.89	889.73	−1.45	1.45	24.50

continued on following page

Table A7 (continued)

	Change in Stocks (million lbs)	Stock Trading Profit[a] (million 2003 $)	Value of Production (million 2003 $)	Trading Profit as a Share of Value of Production (percent)		Stocks/ Production (percent)
	$(S_t - S_{t-1})$	(π_t)	(V_t)	$(100 \times \pi_t / V_t)$	$(100 \times \lvert\pi_t\rvert / V_t)$	$(100 \times S_t / Q_t)$
2036	5.77	−6.99	916.84	−0.76	0.76	24.62
2037	12.99	−15.74	955.30	−1.65	1.65	24.49
2038	9.46	−11.46	984.90	−1.16	1.16	24.61
2039	16.83	−20.39	1,024.60	−1.99	1.99	24.48
2040	12.42	−15.04	1,055.84	−1.42	1.42	24.60
2041	20.69	−25.06	1,096.91	−2.29	2.29	24.44
2042	3.11	−3.77	1,125.00	−0.34	0.34	24.77
2043	29.27	−35.47	1,175.78	−3.02	3.02	24.36
2044	−9.99	12.11	1,197.38	1.01	1.01	25.00
2045	33.98	−41.16	1,265.25	−3.25	3.25	24.32
2046	−9.35	11.33	1,287.88	0.88	0.88	24.95
2047	36.38	−44.08	1,360.29	−3.24	3.24	24.28
2048	12.07	−14.62	1,389.31	−1.05	1.05	24.66
2049	19.58	−23.72	1,439.92	−1.65	1.65	24.59
2050	39.47	−47.82	1,479.76	−3.23	3.23	24.42
Mean for 50-Year Horizon, 2000–2050[b]						
	8.39	−10.17	698.27	−1.34	1.47	24.41
Mean for 20-Year Horizon, 2000–2020[b]						
	3.55	−4.31	351.90	−1.16	1.25	24.25
Mean for 20-Year Horizon, 1979–2001[c]						
	2.08	−2.65	144.69	2.93	23.00	37.35

Note: All monetary values are in real 2003 dollars.

[a] Stock trading profit is the product of change in stocks and current price.

[b] Mean of simulated values in the table.

[c] Mean of actual values, which are not included in the table.

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