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A tale of two commodities: how EU mycotoxin regulations have affected U.S. tree nut industries

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Abstract

The European Union (EU) has some of the strictest standards for mycotoxins in food and feed in the world. This paper explores the economic impacts of these standards on other nations that attempt to export foods that are susceptible to one mycotoxin, aflatoxin, to the EU. The current EU standard for total aflatoxins in food is 4 ng/g in food other than peanuts, and 15 ng/g in peanuts. Under certain conditions, export markets may actually benefit from the strict EU standard. These conditions include a consistently high-quality product, and a global scene that allows market shifts. Even lower-quality export markets can benefit from the strict EU standard, primarily by technology forcing. However, if the above conditions are not met, export markets suffer from the strict EU standard. Two case studies are presented to illustrate these two different scenarios: the U.S. pistachio and almond industries. Importantly, within the EU, food processors may suffer as well from the strict aflatoxin standard. EU policymakers should consider these more nuanced economic impacts when developing mycotoxin standards for food and feed.

Keywords: aflatoxin, European Union, economic impacts, pistachios, almonds

1. Introduction

The European Union's (EU) regulation on aflatoxins is among the strictest in the world, at 4 ng/g total aflatoxins in food other than peanuts, and 15 ng/g in peanuts. Several studies have indicated that this standard could cause severe economic losses to food exporters in the United States (U.S.), China, Argentina, and Africa (Otsuki *et al.*, 2001; Wu, 2004), without any noticeable gain in health benefits to European consumers. Another study (World Bank, 2005) indicated that Otsuki *et al.* had overestimated the impact of the EU aflatoxin standard on Africa, and that the largest losses were incurred by Turkey, Brazil, and Iran. However, the above-described economic studies are based on partial-equilibrium models that do not take into account the multiple stakeholders and price fluctuations that are inherent in adjusting to the EU standard. Moreover, they do not account for the fact that in certain circumstances, a stricter food standard can actually result in economic benefits to high-quality export markets.

This research corrects these problems by using general equilibrium principles, to show how the EU aflatoxin regulations can in some cases hurt and in some cases help export markets. It explores who really benefits and who suffers as a result of strict food standards. The economic impact of the strict EU aflatoxin regulation to its own food markets is explored using theoretical microeconomic principles. Two case studies of impacts abroad are presented, of the U.S. pistachio and almond industries.

2. Background on aflatoxin

Aflatoxins are secondary metabolites of the fungi *Aspergillus flavus* and *A. parasiticus*, which colonize maize, peanuts, pistachios, almonds, hazelnuts, cottonseed, and other crops. Aflatoxin B_1 is the most potent naturally-occurring human liver carcinogen known. Acute aflatoxicosis, characterized by haemorrhage, acute liver damage, oedema, and possible death, can result from extremely high doses of aflatoxin. More common are health effects associated with chronic low to moderate levels of aflatoxin consumption. For people who are infected with hepatitis B and C (common in China and sub-Saharan Africa), aflatoxin consumption raises more than tenfold the risk of liver cancer compared with either exposure alone (Groopman and Kensler, 1996). Aflatoxin consumption is also associated with stunting in children (Gong *et al.*, 2000) and immune system disorders (Turner *et al.*, 2003).

Aflatoxin B_1 also causes a variety of adverse effects in different animal species through DNA modification and cell deregulation. The most prominent effects are liver damage, gastrointestinal dysfunction, and immunosuppression (Wogan, 1973; Norred, 1986; Richard, 1991). In poultry, aflatoxin causes liver damage, impaired productivity and reproductive efficiency, decreased egg production in hens, inferior egg-shell quality, inferior carcass quality, and increased susceptibility to disease (Edds and Bortel, 1983; Wyatt, 1991). Swine that consume aflatoxin experience weight loss, anorexia, ataxia, tremor, coma, and death (Coppeck *et al.*, 1989). In cattle, the primary symptom is reduced weight gain as well as liver and kidney damage. Milk production is reduced and aflatoxin M_1 is excreted in the milk (Keyl, 1978; Guthrie, 1979; Price *et al.*, 1984).

Because of the multiple adverse health effects to humans and animals caused by aflatoxin consumption, many nations worldwide have regulatory standards on aflatoxin in food and feed (Van Egmond and Jonker, 2004). It is important to note that these standards vary greatly among countries, requiring harmonization to remove the variability. Currently, the Codex Committee on Food Additives and Contaminants (CCFAC), which among other activities establishes or endorses permitted maximum levels for additives and contaminants, has set two aflatoxin-related standards: one for peanuts destined for further processing (15 ng/g) and one for aflatoxin M_1 in milk (0.5 ng/g). However, it has been exceedingly difficult to reach nation-to-nation consensus on maximum allowable levels. Major impediments to consensus are the wide variation in aflatoxin levels in crops worldwide, and the relative ability of different nations to reduce aflatoxins in a cost-effective way (Wu, 2006). Of course, harmonization of aflatoxin standards is not necessarily the answer to minimizing health-related losses, as dietary habits and prevalence of hepatitis B and C in different nations must be taken into account. However, harmonizing standards eases world food trade and any disputes regarding aflatoxin contamination that may arise between importing and exporting nations.

3. EU aflatoxin standard and food import regulations

The EU has one of the strictest aflatoxin standards for food in the world, at 4 ng/g total aflatoxins for all foods except peanuts. As aflatoxin is a genotoxic carcinogen, the EU has an interest in keeping it to the lowest level using the ALARA principle (As Low As Reasonably Achievable). This has a strong potential impact on nations attempting to export foods that are susceptible to aflatoxin contamination into the EU. Otsuki *et al.* (2001) estimated a $670 million annual loss to African nations attempting to export food crops to the EU, due to the 4 ng/g aflatoxin standard. Wu (2004) estimated a $450 million annual loss to the U.S., China, Argentina, and sub-Saharan African peanut markets if the EU aflatoxin standard were adopted worldwide.

While these studies were based on theoretical models, it is also true that the EU regulates food and feed carefully, informed in part through its Rapid Alert System for Food and Feed (RASFF). The RASFF is a tool to exchange information on potential risks entering the food and feed system at any point in the EU, to alert all EU Member States to take the appropriate measures to assure food and feed safety (EC, 2006a). The RASFF has had much more impact on EU-wide acceptance or rejection of imported food since the General Food Law was published in 2002 (EC, 2002). Multiple food quality problems are targeted, including, but not restricted to, dioxins, residues of veterinary medicinal products, illegal dyes, microorganisms, lead and other heavy metals, and illegal processes such as treatment of tuna with carbon monoxide (EC, 2006a).

In 2005, mycotoxins, especially aflatoxin, became a contaminant of specific interest that received an increased occurrence of RASFF notifications. In that year, the RASFF received a total of 993 notifications on mycotoxins, 947 of which concerned aflatoxin (EC, 2006a). Aflatoxins were found at levels above 4 ng/g in multiple commodities imported into the EU, including pistachios, peanuts and their derived products, hazelnuts, almonds, chilli, paprika, curry, and nutmeg. Though most of these notifications were for products originating from Turkey, Iran, and China, a large number also came from U.S. products. This is discussed in greater detail below.

4. Economic theory: impacts of imposing a strict food quality standard

Microeconomic theory can give some preliminary guidance as to the economic impacts of the EU's strict aflatoxin regulation. We start by asking: does it ultimately help or hurt to have one market in the world (EU) that imposes a strict food quality standard? There are two different groups of interest regarding impacts: impacts on nations attempting to export under the strict standard, and impacts on the group imposing the strict standard.

On a global scale, having one strict importer creates a more tiered market, similar to the automobile industry. (We shall use the automobile industry several more times as an analogy in this section.) Those consumers who do not have such high standards can buy lower quality food at a lower price, whereas those who do have high standards (EU) can buy higher-quality food at a higher price. This is analogous to those who have the money and the desire to buy luxury cars, compared with those who have less money, less desire for luxury, or both, who would buy less expensive cars.

Such an arrangement – one nation imposing a strict aflatoxin standard – certainly benefits high-quality food producers (e.g. California pistachio producers). This is because now their high-quality goods are recognized in the market; whereas before, their higher quality may not have resulted in a price premium. Also, there is motivation worldwide to produce a higher quality product, when a higher price is offered for it.

Does the strict aflatoxin standard benefit *consumers*? This depends on whether consumers experience value through the higher quality good. From a purely health-related perspective, it does not benefit consumers significantly to have a 4 ng/g aflatoxin standard as opposed to a more relaxed standard (Henry *et al.*, 1999).

However, EU consumers may not be the ones to bear the brunt of the cost. Rather, the cost is likely to be borne primarily by *EU food processing industries*. This is due to three economic principles: supply shortage, price elasticity of demand, and substitutability of goods:

1. The global supply of foods that can meet the 4 ng/g standard is smaller than the supply that can meet a more obtainable standard (e.g. the U.S. FDA standard of 20 ng/g), so EU food processors must pay higher prices to find quality products.
2. Food processors cannot pass all of this cost onto the consumers, because the price elasticity of demand P_d for luxury foods (e.g. tree nut products) is high; meaning that a unit increase in price will result in drastically reduced demand for the good.
3. Moreover, luxury goods are highly substitutable. If the price of one luxury item increases, consumers are likely to forego buying that item and will spend their income on a different luxury item.

These principles, though theoretical, can help explain consumer behaviour in the face of stricter food safety standards on luxury goods. If consumers did *not* decrease their demand in the light of high prices, then the price elasticity of demand would, by definition, be low. But there are some goods (including food goods) for which price elasticity of demand is high, and tree nuts fall into this category. As to the extent to which the consumer pays, that depends again on price elasticity of demand. If the price of a good increases too much, consumers will simply stop buying the good; or far fewer consumers would buy it. One could argue that consumers 'pay', in that they would prefer to buy the good at a reasonable price than not to buy it at all. But the food industries are the most immediately affected by an increase in the tree nut price.

Figure 1 illustrates the dynamics of supply and demand when supply is decreased. The original equilibrium of quantity supplied Q_0 and price per unit good P_0 is the intersection of the demand curve with the original supply curve S_0. However, when the supply curve is shifted left to S_1 (as happens when supply is decreased), a new equilibrium is reached; represented by the intersection of the demand curve with the new supply curve S_1. The reduced quantity of sold items Q_1 demands a higher price per unit item P_1.

From the point of view of food processors in the EU, a strict aflatoxin standard imposed by the EU will result in a decreased supply of aflatoxin-vulnerable commodities such as pistachios and almonds; because there are very few export markets that can consistently provide these goods at such a high quality standard. As a result, the price for these high-quality goods increases and food processors must pay the cost. Specifically, the decrease in food processors' welfare is represented by the shaded area in Figure 1. This area represents the difference between the initial welfare (area of triangle bounded by P_0, Q_0, and demand curve) and resulting welfare (area of triangle bounded by P_1, Q_1, and demand curve).

Though EU food processors incur this extra loss due to price increase for foods, they cannot pass all of this loss onto consumers in the form of higher-priced food products. This is because the absolute value of price elasticity of demand P_d for luxury goods (including confections made from pistachios, hazelnuts, and almonds) is high; that is, a unit increase in price results in much lower consumption of that product. As illustrated in Figure 2, this high P_d results

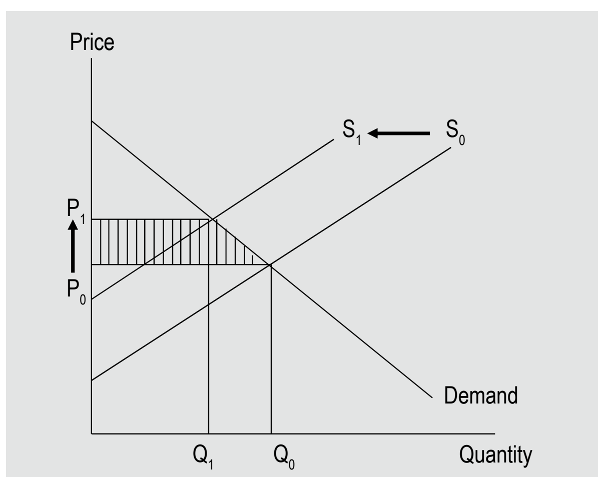

Figure 1. The impact of a strict food quality standard on supply and subsequent price.

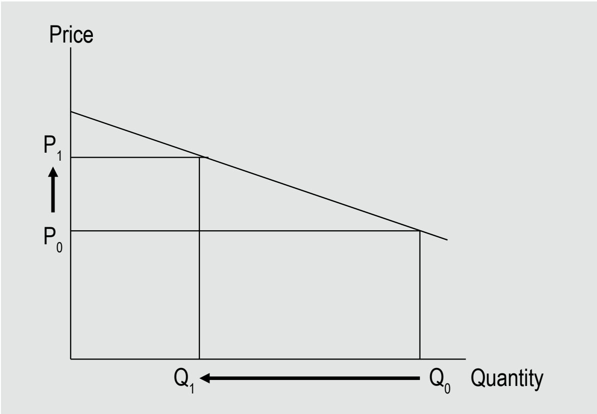

Figure 2. Shallow price elasticity of demand P_d for luxury goods.

in a demand curve with a shallow slope. A unit increase in the price of a food item ($P_0 \rightarrow P_1$) would greatly reduce the quantity bought of that food item ($Q_0 \rightarrow Q_1$). This phenomenon is referred to as the 'income effect'. Hence, it is not in the best interest of EU food processors to raise the price of their products, even if the strict aflatoxin standard increases their operating costs.

Moreover, luxury goods are highly substitutable. If the price of one good increases (due to a strict food quality standard), the consumers' 'allowable budget' curve decreases on quantity of that good purchased. That is, they will spend less money on that particular good. Consumers are likely to purchase more of a less expensive good: the 'substitution effect'. Figure 3 shows how changes in budget constraint for a given luxury good will result in decreased purchase of the good for which the price increased (N_1) and increased purchase of an alternative luxury good (C_1). The indifference curves represent the ratio of two luxury goods for which a consumer derives equal utility. For example, extrapolating either upwards or to the right, consumers would demand a great deal of one good if they were not able to obtain any of the other good, in order to make their overall utility the same as if they could easily access both goods. For example, if the price of marzipan, made from almonds, increases, consumers are likely to forego buying it and may buy another kind of confection instead, such as chocolate.

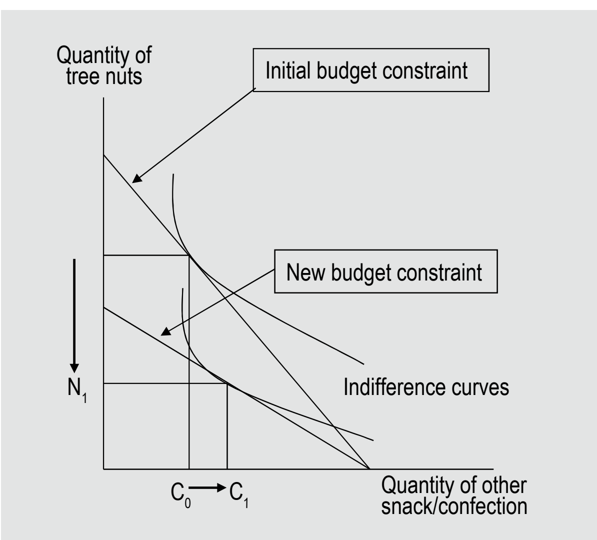

Figure 3. Substitutability of two goods when the price of one good increases.

Hence, microeconomic principles give insight into several possible effects of the strict EU aflatoxin standard on EU food processors. First, the food processors must pay higher prices for commodities due to the limited supply of goods that can meet the high quality standard. Also, food processors cannot pass this cost onto consumers, because the substitution and income effects will mean that consumers purchase less of the food products and will instead turn to buying other products.

5. Impacts on markets attempting to export to EU: case studies

What is the situation for the producers, i.e. those nations that attempt to export goods vulnerable to aflatoxin into the EU? One might assume that there will be an adverse economic impact, as goods are more likely to be rejected for aflatoxin levels that exceed 4 ng/g. Indeed, Otsuki *et al.* (2001) and Wu (2004) estimate the economic losses due to the EU aflatoxin standard to be several hundreds of million USD annually. However, the situation is more complicated than this, based on the quality of the good in question.

Let us examine two case studies: U.S. pistachios and almond exports to the EU. Pistachios and almonds are both goods that are susceptible to aflatoxin contamination. However, levels of contamination susceptibility vary substantially from nation to nation. Almonds and pistachios in the U.S. share important similarities: they are produced exclusively in the state of California; the bulk of aflatoxin-related loss is borne by handlers, who buy even low-quality nuts from growers in order to maintain relationships on a long-term basis; aflatoxin contamination is highly correlated with insect damage; sorting to remove 'inedibles' (including, indirectly, nuts with aflatoxin) is fairly easy and mechanized; and, most importantly, *export markets* play a key role in determining the economic impact of aflatoxin – particularly exports to the EU, which imports a large quantity of U.S. tree nuts. 45% of U.S. pistachios are exported, and 67% of U.S. exports go to the EU (USDA, 2005a). 70% of U.S. almonds are exported: 62% to the EU (USDA, 2005b). It is on this last point – exports to the EU – that significant differences exist in aflatoxin's economic impacts upon pistachios and almonds.

The U.S. pistachio industry provides an example of a market that has benefited from strict EU standards, for two reasons: (1) the consistently high quality of the product, and (2) the ability to shift markets on a global scale. Since the enforcement of the new EU aflatoxin standard, the U.S. has actually *increased* its monetary market value of pistachio exports to the EU almost five-fold. Figure 4 shows the yearly value of U.S. pistachio exports to the EU since 1998, when the 4 ng/g aflatoxin standard first took effect. (2004 is the last year for which public data are available on U.S. pistachio exports. All monetary values in this figure and in following figures have been translated into 2006 USD.) The major EU importers for U.S. pistachios are Belgium, Luxembourg, the Netherlands, France, and Italy (USDA, 2005a).

Even other pistachio-exporting nations have benefited from the strict EU aflatoxin standard. This is because of a phenomenon commonly referred to as 'technology forcing', and is best demonstrated in the Iranian pistachio industry. Prior to 1998, Iran produced pistachios with extraordinarily high levels of aflatoxin. These high levels prompted an emergency EU-wide ban on Iranian pistachios and pistachio products in 1997 (EC, 1997). Since the EU ban and its aflatoxin standard went into effect, the Iranian pistachio industry has dramatically changed the means by which pistachios are handled, in order to reduce aflatoxin contamination. Before 1997, Iranian pistachios were dried on concrete slabs open to the air, exposing them to fungal spores, insects, rain, and other factors that predispose pistachios to aflatoxin contamination. After the EU ban, pre-harvest and post-harvest technologies were adopted to greatly reduce aflatoxin-related problems (Ketabi, 2005). The quality of Iranian pistachios has improved so much that the value of its export market to its main importer Hong Kong, which has a total aflatoxin standard of 15 ng/g, has increased significantly since 1998 (see Figure 5).

Over this time period, Iran's pistachio exports to the EU have remained roughly the same, but as partially shown

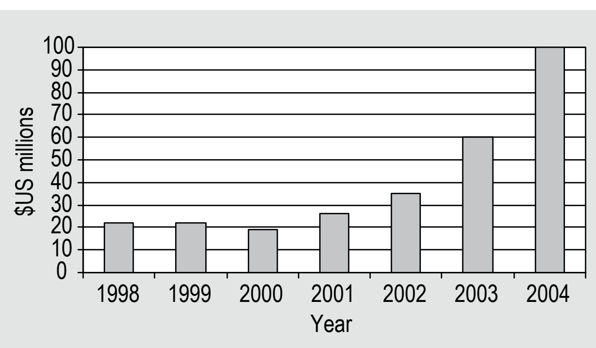

Figure 4. U.S. pistachio exports to the EU, 1998 to 2004 (USDA, 2005a).

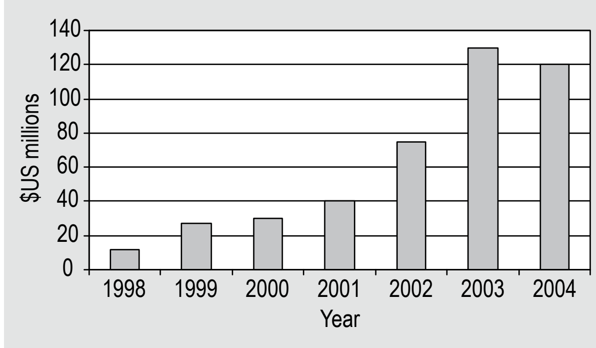

Figure 5. Iranian pistachio exports to Hong Kong, 1998 to 2004 (USDA, 2005a).

in Figure 5, its exports to less-strict markets worldwide have increased significantly since 1998 (USDA, 2005a). Given that the U.S. and Iran are two of the major pistachio producers worldwide, what appears to have happened over the last decade is that overall pistachio consumption has increased, overall quality of the pistachios (i.e. lower aflatoxin levels) has improved, and market shifting has taken place: the U.S. sells pistachios to the EU at a higher price, and Iran sells to less strict markets at a lower price.

Thus, who are the economic winners and losers in the case of pistachios and aflatoxin levels? The global pistachio industry's improved aflatoxin control in the last decade appears to have created a win-win situation for all stakeholders. Though overall pistachio production has not increased significantly over the decade (USDA, 2004), the market value to the two major exporters U.S. and Iran has increased steadily over that time. This is because technology forcing to reduce aflatoxin in Iran, the largest producer of pistachios worldwide, has led to an increase in the overall supply of high-quality (low-aflatoxin) pistachios globally. When supply increases, demand almost always increases simultaneously, resulting in increased overall welfare. This increased demand usually takes place through price reduction, although other ways to increase demand include advertisement and other outreach activities.

In fact, the U.S. pistachio industry, which has experienced few EU RASFF notifications for aflatoxin (about 10 or fewer alerts per year; EC, 2006a; Dr. Bruce Campbell, personal communication), hopes to establish an Origin Certification Program (OCP) with the EU (Mr. Robert Klein, Administrative Committee for Pistachios, personal communication). With an OCP, the aflatoxin testing would almost entirely occur at the exporter's end, with only occasional tests at the importer's (EU) end. Symbolically, it represents the EU's trust in the quality of U.S. pistachios. Such an OCP already exists between the U.S. and the EU for peanut trade (Adams and Whitaker, 2004).

The U.S. almond industry has had quite a different experience with the EU aflatoxin standard. The U.S. is the largest exporter of almonds globally, representing about 80% of the world almond market (USDA, 2005b). 67% of U.S. almond exports are intended for the EU, with Spain and Germany being the main importers (USDA, 2005b). Given that such a large proportion of U.S. almonds are already going to the EU, there is very little room for global market shifting; i.e. if the EU rejects U.S. almonds, it is difficult to sell them elsewhere in the world at a comparable price.

Indeed, unlike the case with U.S. pistachios, the value of U.S. almond exports to the EU has *not* increased significantly since 1998 (see Figure 6). Moreover, in the last several years, the U.S. almond industry has experienced a large number of EU RASFF rapid alerts and information notifications (*28* notifications in 2005 and *36* notifications in 2006, EC, 2006a; and *over 50* notifications in 2007, Julie Adams, personal communication), which amount to \$10,000-\$15,000 in rejection costs each. The rejection costs include: testing and sampling, transportation, demurrage (storage, time, and labour costs), and financial adjustments and reprocessing of noncompliant shipments (Mr. Merle Jacobs, American Council for Food Safety and Quality, personal communication).

Though the actual proportion of market value to the U.S. almond industry from EU almond rejections is relatively small (less than 1% of the total value of U.S. almond exports to the EU), the number of notifications has risen steadily over the last several years; and concerns about almond quality may have undesired long-term consequences.

In September 2007, however, the Almond Board of California's Voluntary Aflatoxin Sampling Plan (VASP) went into effect. VASP provides an alternative aflatoxin sampling plan for the U.S. almond industry with an equivalent sensitivity to that being used in the EU. Commission Regulation No 401/2006 (EC, 2006b) was used as the guideline for lot size and sample frequency (Almond Board of California, 2007).

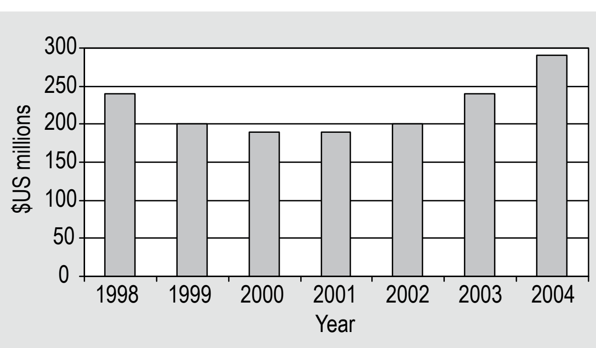

Figure 6. U.S. almond exports to the EU, 1998 to 2004 (USDA, 2005b).

The goal of VASP is to reduce lots rejected in the EU market. In part, the VASP guidelines were developed in response to EU concerns about U.S. almond quality. In January 2007, the EU proposed that 'special measures' be applied to U.S. almond imports, because the EU Food and Veterinary Office (FVO) visit in the previous month concluded that U.S. almond aflatoxin control was inadequate. The EU measures require 100% surveillance: every almond consignment from the U.S. would be tested for aflatoxin. Now with VASP, however, U.S. almonds that have been tested under the VASP protocol prior to shipment and accompanied by a VASP certificate are subject to only 5% surveillance (Almond Board of California, 2007).

At the moment, it is too early to tell how VASP will affect the number of rejections the U.S. almond industry will experience from the EU. Presumably this number will be lower because of the lower surveillance rate. However, losses may then be incurred on the domestic side during VASP surveillance, which means that the economic burden of rejection is simply shifted from importing to exporting time. One direct economic benefit of VASP, however, is that even if almonds are rejected during domestic sampling, U.S. almond handlers will not have had to suffer the same costs associated with transportation to the EU, demurrage, docking fees, etc. This lowers the overall cost of aflatoxin sampling.

6. Discussion

The theoretical and empirical economic analysis presented in this manuscript lead to several conclusions regarding the impact of the strict EU aflatoxin standard.

The EU – primarily food processing industries, and secondarily consumers – may in theory suffer a substantial economic loss from its own strict aflatoxin standards. This is because the strict standard results in a drastically reduced supply of goods to food processors, which increases market prices. Food processors cannot pass all of this cost onto consumers due to the substitution and income effects, which are enhanced by the luxury nature of the products (pistachios and almonds). Moreover, though the aflatoxin standard is intended to protect human health, health benefits to consumers from such a standard are insignificant (Henry *et al.*, 1999).

From the producers' side, under certain conditions, an export market (e.g. U.S. pistachios) may actually *benefit* from the strict EU aflatoxin standard. These conditions are (1) a consistently high-quality good, and (2) a global scene that allows market shifts (i.e. high differentiation in quality among multiple exporters). Even lower-quality export markets may benefit from a strict aflatoxin standard abroad, because it forces them to adopt technologies and methods to control food quality. In the case of Iranian pistachios, this has meant improved use of pre-harvest and post-harvest means to control aflatoxin, resulting in safer foods both domestically and abroad, and better market returns.

On the other hand, if the two conditions above are not in place, export markets are more likely to suffer as a result of the strict EU aflatoxin standard. In particular, rejections of shipments incur increasingly significant costs. This is demonstrated by the lack of increased EU market share for the U.S. almond industry, and the increasing number of EU notifications it has suffered due to excessively high aflatoxin levels.

EU policymakers must consider these more nuanced economic impacts in order to understand the potential adverse effects of their own regulations. Indeed, this type of analysis may prove useful in the development of future food quality regulations, either of mycotoxins or other contaminants.

Acknowledgments

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