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E. coli in Spinach, Foodborne Illnesses, and Expectations about Food Safety

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The FDA and the produce industry have recognized the potential for E. coli contamination of leafy greens for some time and numerous safeguards were already in place at the time of the recent E. coli outbreak. The failure to prevent or detect the E. coli before the contaminated spinach entered the market amplifies the demand for improved quality assurance in the food supply in general, and produce in particular. There are over 40 billion servings of salad consumed in the United States each year, of which almost three billion are fresh spinach, illustrating the enormity and the importance of the task.

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The Center for Disease Control estimates that every year 76 million people in the United States become sick from foodborne illness, 325,000 are hospitalized, and 5,000 die. They further estimate that over 12 percent of these illnesses are linked to produce (i.e., fresh fruits and vegetables). This means that in any given year, we should expect 39,000 hospitalizations and about 60 related deaths due to foodborne illness related to produce. If these illnesses are spread out evenly throughout the year, the expectation becomes 750 hospitalizations and slightly over one death per week attributable to produce consumption. It follows that the 2004 illnesses, including 102 hospitalizations and three deaths, traced to bagged spinach over a three-week period starting September 13, 2006, although tragic, were not out of the norm in terms of numbers. In fact, between 1995 and 2005, 19 individual outbreaks of E. coli foodborne illness were attributed to fresh-cut lettuce and one outbreak in 2003 attributed to fresh-cut spinach resulted in two deaths. Therefore, the recent outbreak of E. coli associated with bagged spinach from California arguably may be more an indication of the efficiency and concentration in the produce distribution system, sophisticated traceability mechanisms in place, and effective government communication rather than an unprecedented spike in the risk level of foodborne illness.

Regrettably, investigators never identify the source for the vast majority of incidences of foodborne illness. What is most notably different about the recent outbreak related to fresh-cut spinach is that there are now 13 confirmed samples of bagged Dole Baby Spinach containing the outbreak strain of E. coli. Precisely because the spinach was bagged and all bagged products contain lot codes on the packaging, the Food and Drug Administration (FDA) could quickly trace these samples back to one shift at the Natural Selection Foods packing facility in San Juan Bautista, California and, eventually, four spinach fields in the Salinas Valley. The outbreak drew national attention due to the geographic dispersion of the reported illnesses spanning 26 states. But although the FDA eventually narrowed the location of the investigation, it has been unable to identify the mechanism of contamination or rule out additional cross contamination. Therefore, neither the industry nor the FDA can assure consumers that the problem is solved or that similar problems will not arise in the future. For many consumers, the advisory to avoid bagged spinach has evolved into apprehension about all spinach, all bagged salads, and any type of salad even though no E. coli was found on lettuce and none of the contaminated spinach was grown outside of the Salinas Valley. The Mexican government's temporary refusal of lettuce shipments from the United States and

Table 1. U.S. Per Capita and Total Consumption of Lettuce and Fresh Spinach, 2004

	Fresh Spinach	Leaf Lettuce	Head Lettuce	Total
Per capita consumption (pounds)	1.8	11.2	20.9	33.9
Per capita servings per year	10	59	111	180
Number of servings (billion)	3	17	33	53

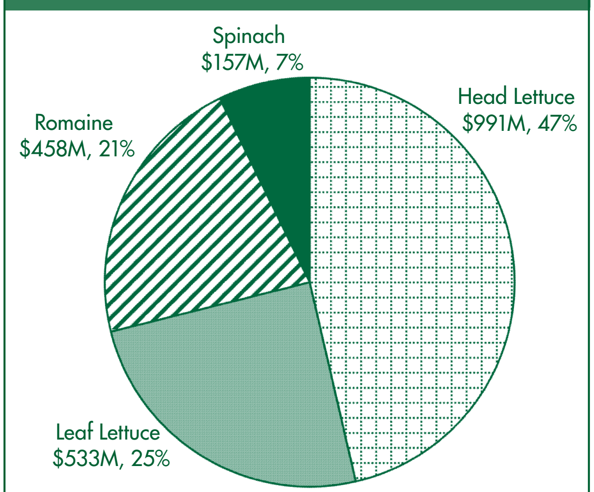
Canada's refusal to accept any U.S. spinach further fueled fears.

Economic Impacts

The long-term economic impact on agriculture is still uncertain and depends almost entirely upon consumer response in terms of changes in patterns of leafy-green consumption and the duration of those changes. Fresh spinach sales totaled $157 million in 2005 and accounted for only seven percent of the $2.1 billion in sales of leafy greens. Almost half of leafy-green sales were head lettuce, one-fourth leaf lettuce, and one-fifth romaine (Figure 1). Looking at harvested acreage, California represents about three-fourths of all lettuce and fresh spinach acreage in the United States (Figure 2). This means that a disruption in the sale of spinach in particular, and leafy greens overall, is a California problem.

The produce industry in California has benefited from increasing demand for leafy greens. Over the past decade, per capita consumption of leafy greens increased from about 26 pounds per person a year to 34 pounds (Table 1). Fresh-spinach consumption is only a fraction of this but showed rapid growth from 0.6 pounds per person in 1994 to 1.8 pounds in 2004. This rate of consumption translates into 180 servings of salad per person a year; roughly a salad every other day. It also means that there are over 50 billion servings of salad consumed in the United States each year, of which almost three billion are fresh spinach. About 80 percent of households purchase salad, with consumption tending to be slightly lower for families earning less than $20,000 per year (Figure 3). Consumers of all ages purchase spinach, with only a slight decline noticed in consumers over 59 years of age (Figure 4).

Figure 1. 2005 Farmgate Value of Leafy Greens: $2.1 Billion



Source: National Agricultural Statistics Service

According to the International Fresh-Cut Produce Association, fresh-cut produce sales totaled $15 billion in 2005 through all market channels and $6 billion at retail alone, accounting for about 16 percent of all supermarket produce sales. Packaged salads are slightly over half of all fresh-cut supermarket sales, totaling over $3 billion in 2005. About half of all produce enters the food supply through food service (restaurants, hospitals, military, and cafeterias) but no data are available for sales by category.

Efforts to Reduce Risk

The FDA and industry have recognized the potential for E. coli contamination of leafy greens for some time. In 1998 the FDA issued the "Guide to Minimize Microbial Food Safety Hazards for Fruits and Vegetables," including Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs), now recognized as industry standards. In February 2004, the FDA wrote a letter to the lettuce and tomato industries airing concerns regarding continuing outbreaks of foodborne illness. Later that year, the FDA posted its "2004 Produce Safety Action Plan" and in late 2005, issued a letter to California firms that grow, pack, process, or ship fresh and fresh-cut lettuce.

The FDA further developed the Lettuce Safety Initiative to support the goals of the action plan and to coordinate with the California Department of Health Services and Department of Food and Agriculture in recognition that a majority of outbreaks of E. coli related to lettuce were traced back to production in California. The initiative's objectives are summarized as follows:

1) Assess current industry approaches and actions to improve lettuce safety;
2) Alert consumers early and respond rapidly in the event of an outbreak;
3) Identify practices that lead to contamination and then develop or refine guidelines and policy that will minimize future outbreaks, and
4) Consider regulatory action.

The Agricultural Marketing Service (AMS) of the U.S. Department of Agriculture began a voluntary program called Qualified Through Verification (QTV) for the fresh-cut produce industry in 1996. The user-fee program works with individual companies to develop a hazard-analysis plan tailored to their production facility and verifies effectiveness though unannounced on-site audits. Among other safeguards, the AMS expects firms to test for E. coli as assurance of good sanitation practices. The program promotes proactive prevention of contamination during production, as opposed to detection after the fact. The QTV validation program provides firms with a means of quality assurance for their customers.

Jumping to Conclusions

During the recent E. coli outbreak, early suspicions focused on organic agriculture because of the common practice of using composted manure as fertilizer. However, federal law requires manure used as fertilizer in organic production to be fully composted, which would kill any E. coli present. Further, conventional vegetable growers typically also use composted manure on their fields to improve water infiltration. At the same time, grower groups blamed packers and processors blamed growers. Public criticism also turned to concentration in vegetable production and distribution. At the time of the outbreak, the packing facility linked to the outbreak, owned by Natural Selection Foods, packed for over 30 labels and provided spinach to five other companies. Those companies also issued recalls. Natural Selection Foods farms 24,000 acres of its own and also buys from numerous other growers. Under its Earthbound label, Natural Section salads are available in three-fourths of all grocery stores in the United States.

Two companies, Dole and Fresh Express, account for 88 percent of the packaged salad sold in the United States. This level of market penetration provides a situation where contaminated product can cross the nation in a short period of time. But it also creates a situation where large grower/shippers have the money and motivation to invest in food safety programs. However, the quality assurance from a grower/shipper is only as high as that of its poorest grower.

Quality Assurance

The recent E. coli outbreak amplifies the demand for improved quality assurance in the food supply in general, and produce in particular. Increased assurance inevitably means increased spending. The obvious question becomes whether it is most cost-effective to improve prevention of contamination or improve detection, given a finite quality assurance budget. Natural Selection and other major facilities already:

(1) Maintain sanitation programs following Good Manufacturing Practices developed by the FDA;

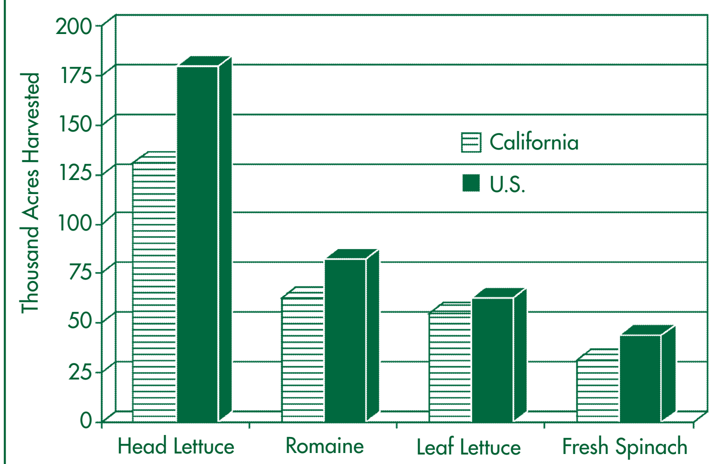
(2) Employ a quality assurance supervisor to continuously monitor chlorine levels of rinse water and the temperature of the plant;

(3) Hire an independent lab to test for bacteria as part of their quality assurance programs, and

(4) Participate in the QTV Program.

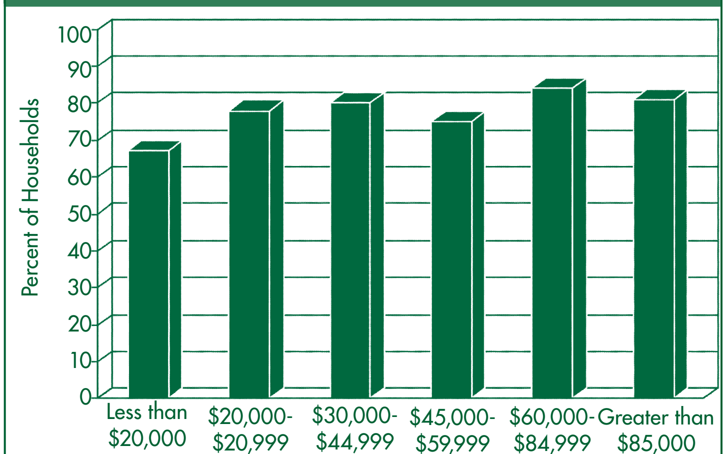
Natural Selection has issued a statement that they will

Figure 2. 2005 Production of Leafy Greens in the United States and California



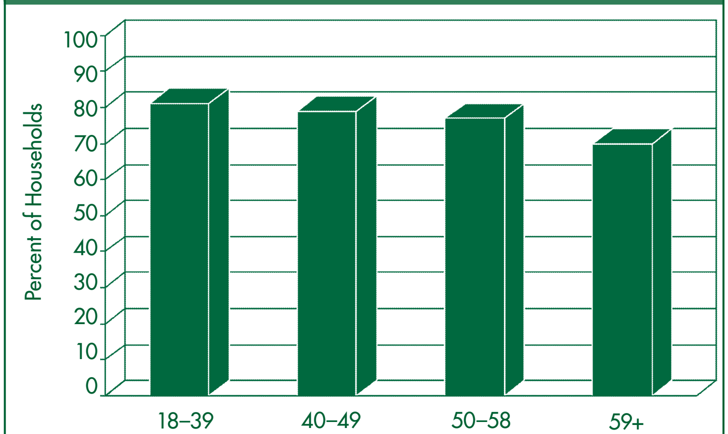
Source: NASS

Figure 3. Percent of Households Purchasing Salad by Income, 2005



Source: Produce Marketing Association

Figure 4. Percent of Population Purchasing Salad by Age, 2005



Source: Produce Marketing Association

"now be testing all of the freshly harvested greens before they enter our production stream." They will also be working directly with growers "from seed to harvest, inspecting seed, irrigation water, soil, soil amendments, plant tissues, and wildlife—all of which will be tested, monitored, and certified." These added inspections may prove to be impractical both from a cost and time perspective.

The current and proposed assurances raise further questions. Buyers, such as supermarket chains, set standards for food safety and they require that their suppliers meet these standards. In turn, because there is so much at stake, large grower/shippers and packers are highly motivated to work with individual growers to minimize risks to meet buyers' standards. Third-party private firms offer certification of compliance with Good Agricultural Practices and Good Manufacturing Practices, but the standards for certification are not regulated by the government. There is no government accreditation process for third-party inspectors. Thus far, industry has worked closely with government to develop GAPs and GMPs. The most critical question to answer in the current situation is whether or not problems arose due to a failure to follow known safe practices or if the current situation has brought to light a previously unidentified source of risk. Both scenarios point to the need for additional research to establish new or revised protocols that further reduce the risk of foodborne illness. The current situation also points to the need for an excellent crisis-management plan as part of any quality assurance program. At the same time, while American consumers have every right to demand and expect the highest standards in food quality, they must also accept the fact that zero risk is not a physically attainable goal.

Increased Food Safety Standards

Soon after the FDA lifted the spinach advisory, the Western Growers Association called for food safety regulations for produce. In early November the California Farm Bureau Federation, the largest farm organization in California, followed by announcing it is working with Western Growers

Fresh spinach sales totaled $157 million in 2005 and accounted for seven percent of the $2.1 billion in sales of leafy greens.

Photo: UC Regents

and other organizations "to develop self-imposed mandatory food safety regulations." The statement went on to suggest the possibility of creating a marketing order or marketing agreement to fund the development of mandatory safety standards at all stages of production from farm to table.

In fact, a marketing board already exists for California lettuce. The California Lettuce Research Board, formed in 1973, operates under the authority of CDFA and is financed through assessments on each carton of iceberg and leaf lettuce harvested in California.

In recent years, the board has awarded over half of available funds to breeding for disease resistance. The remaining funds have been for nutrient and cultural research. Future funds could be directed toward the creation of food safety standards.

The FDA publication, "Guidelines to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables," would undoubtedly serve as a starting point. Although they address all known sources of contamination, by design, these voluntary guidelines were not written in regulatory language.

California and federal officials have now found evidence that nearby cattle and wild boar are the probable sources of the recent E. coli contamination. The guidelines include the presence of wildlife and livestock as potential sources of microbial contamination and recommend "to the extent possible, where high concentrations of wildlife are a concern, growers should consider establishing good agricultural practices to deter or redirect wildlife to areas with crops that are not destined for the fresh produce market." Terms like "to the extent possible" are impossible to enforce.

Regulation and enforcement are limited by current scientific knowledge. The FDA guide "focuses on risk reduction not risk elimination." It goes on to say that "current technologies cannot eliminate all potential food safety hazards associated with fresh produce that will be eaten raw." Nonetheless, the European Union and New Zealand are beginning to move toward the adoption of mandatory food safety regulations for fresh produce and away from voluntary guidelines. These actions could put additional pressure on the U.S. industry to implement changes.

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Economics of the California Processing Tomato Market

Colin A. Carter

The California processing tomato industry grew in the 1980s and 1990s but then ran into some problems. This article is a general synopsis of the processing tomato industry today and we find that the fundamentals and prospects are positive.

When you think of tomato paste or tomato sauce, Italy may come to mind. However, California, another wonderful place, is actually the largest supplier of processed tomato products in the world, with about 30 percent of global production. Italy is a distant second. The combined supply from Italy and California accounts for around 50 percent of the world's total. China and Spain are other large producers.

The California processing tomato industry enjoyed substantial growth in the 1980s and 1990s, due to higher-yielding hybrid varieties, high price years, new processing plants, and expanded acreage. However, around 2000, some industry observers predicted that the good times were coming to an end, due to an over-supply of tomatoes in the Golden State. There was a record harvest in 1999-2000, as processors reacted to the highest paste prices in a decade, and inventories built up to about one-half of the annual crop. Tri Valley Growers, one of the largest tomato processors at the time, filed bankruptcy in 2000 and this created great hardship for many growers.

However, this was not the first time that California's tomato processing industry was in trouble. Tomato paste and sauce is a global commodity that has many of the characteristics of a typical agricultural commodity—resulting in boom and bust periods. You might recall that the mechanical tomato harvester "saved" California's processed tomato industry back in the late 1960s.

Six years ago, the doom and gloom predictions for the California industry were based on the following factors:

- relatively high grower returns for processed tomatoes compared to other crops that could lead to surging tomato acreage in the southern San Joaquin Valley;
- tomato grower forward integration creating excess processing capacity;
- declining domestic per capita consumption; and
- increasing international competition.

Pundits predicted that relatively high grower returns for processing tomatoes were going to lead to over-production, a classic farm problem. But the so-called "disequilibrium" in the processed tomato market never fully materialized. Why not? This article will review key trends in the California processed tomato industry to try to answer this question and to outline current issues facing the industry. We find that current prospects for the California processing industry are positive.

Domestic Market

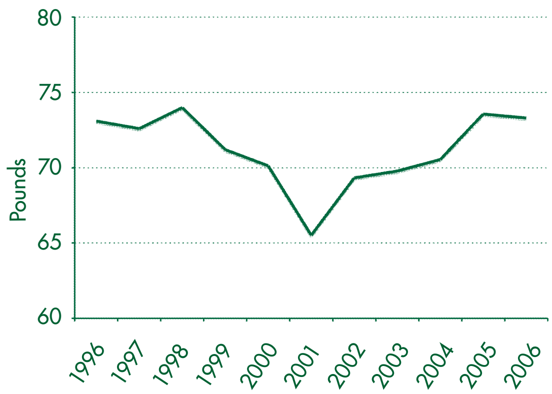
To begin, consider California's tomato acreage. A few years ago it was argued that in the southern San Joaquin Valley of California, processed tomato acreage had huge potential to expand as an alternative to cotton. Cotton was a large but declining crop in the region and the claim was that higher returns for processing tomatoes relative to cotton would lead to a small share of the cotton acreage shifting to tomatoes, resulting in an over-supply of tomatoes. At the time, some growers were also investing in new tomato processing plants and this was viewed as part of the over-supply problem. The industry feared that more grower-owned plants would be constructed.

Enough time has passed that we can now ask whether there was an expansion of tomato acres in California. The answer is no. Over the past decade, there has been no significant growth in processing tomato acreage. Furthermore, there has been no measurable trend in the size of the total harvest, so yields have also flattened out. As a result, California's share of worldwide production of processing tomatoes has declined because production has expanded in places like Western Europe and China.

For the state of California, accurate acreage figures by county are difficult to obtain, but production in the northern growing region of the state has been falling by about three percent per year over the past ten years. This decrease has been offset by an approximate three percent growth in southern valley production (i.e., in Fresno, Kern, and Kings counties). The three big processing tomato counties in California are Fresno, Yolo, and San Joaquin, in order of importance. Yields are higher moving from the north to the south, averaging about 36 tons per acre in Yolo County, 38 tons in San Joaquin, and 40 tons in Fresno.

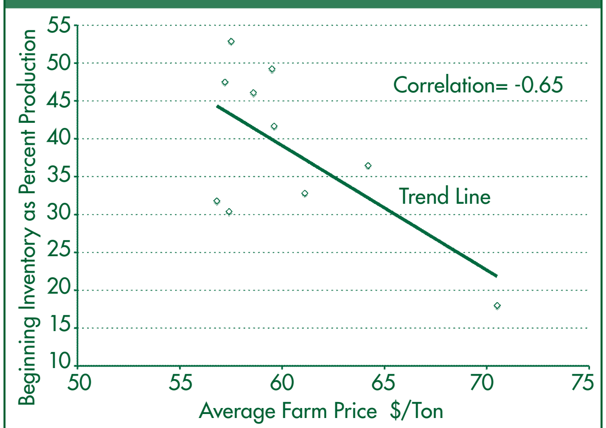
One major reason why acreage has not expanded in the state is that overall processing capacity has not grown appreciably since around 2000. In the 1990s there was significant consolidation in processing. Private and grower-controlled firms built larger and more efficient plants that brought down

Figure 1. U.S. per Capita Consumption of Processing Tomatoes



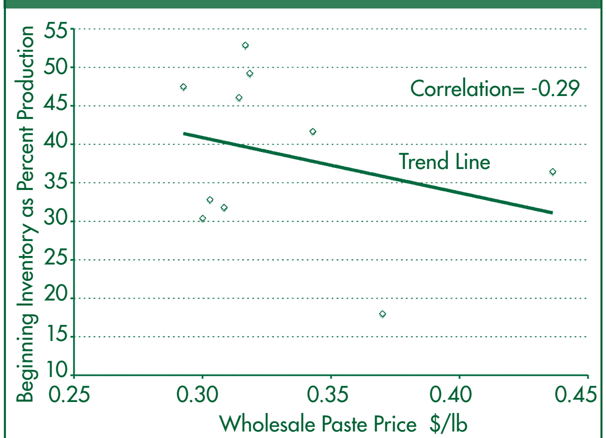
Source: United States Department of Agriculture)

Figure 2. Relationship between Farm Prices and Beginning Inventories: Crop Years 1996 to 2005



Source: Farm Price is fob Processing Plant from USDA/NASS. Inventories as of June 1 from California League of Food Processors.

Figure 3. Relationship between California Wholesale Paste Price and Beginning Inventories: 1996 to 2005



Source: Paste price in 55 gal drums, from The Food Institute. Beginning Inventories as of June 1 from California League of Food Processors.

processing costs and produced a higher-quality paste. The expansion phase then stopped as wholesale tomato paste prices remained relatively low for several years. Since 2000 there has been some rearranging of processing capacity among firms, with the private and grower-owned firms adding some capacity. Overall, the total capacity of the industry has settled at about 5,200 (short) tons of tomatoes per hour, which translates into a processing capacity of approximately 11 to 11.5 million tons per season. In processing tomatoes, it may be the case that "if you build it they will come" so it is quite possible that acreage has been flat since 2000 simply because no new plants were built. For the most part, processors determine tomato acres, not farmers. Growers only plant the acreage for which they can contract. Going forward, if processing capacity is added this will undoubtedly lead to higher acreage; most likely in the southern part of the state.

One piece of good news for the industry is that U.S. per capita consumption of processing tomatoes has recovered from the dip that it took five or six years ago. As shown in Figure 1, per capita consumption of processing tomatoes is now over 73 lbs (farm weight equivalent). This is very high by international standards and is, for example, almost double the per capita consumption level in Europe. This upswing in per capita consumption is important because domestic consumers purchase 90 percent or more of the U.S. production. It would be interesting to examine domestic consumption data across products (sauces, paste, catsup, etc.) but these numbers are not available for recent years.

One striking aspect of the California processing tomato market is the relatively high level of inventories carried from one season to the next, measured as a share of domestic production. During the past ten years, beginning inventories averaged almost 40 percent of production— a high ratio compared to other storable agricultural commodities. The large domestic inventories have important implications for the dynamics of price formation. In particular, inventories help absorb shocks to the market and they serve to mute the impact of supply fluctuations. Inventories flatten the demand curve, so a given supply shock has a smaller impact on price compared to a situation with a lower inventory ratio.

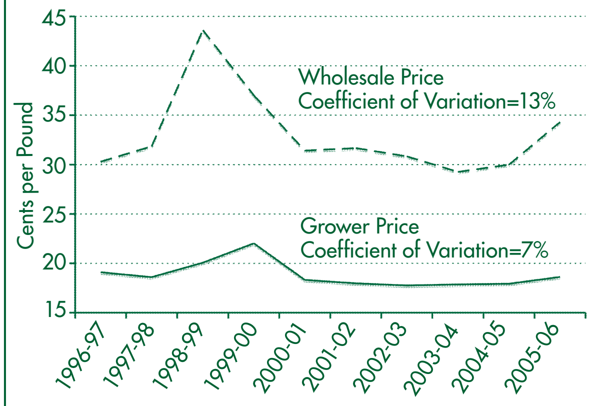
The important role of reported inventories is shown in Figures 2 and 3. Figure 2 displays the relationship between annual prices received by growers (fob processing plant) and beginning inventories as a ratio to production (as of June 1), over the past ten years. The trend line in Figure 2 is quite steep and downward sloping, indicating that a lower beginning inventory ratio is correlated with a higher average farm price. The correlation coefficient (which measures the degree to which two variables are linearly related) between inventories and the farm price is –0.65. Without attributing causation, we can state that this high negative correlation indicates that whenever beginning inventories were large, the farm price tended to be low.

Figure 3 shows a similar pattern between inventories and the wholesale paste price. The correlation between inventories and the paste price is –0.29, suggesting that when inventories were relatively high the paste price was relatively low. The implication is that a build-up of inventories may tend to drag down the domestic paste price, because the market is largely driven by domestic fundamentals.

Almost all of the processing tomato production in California is forward contracted, normally well before the season starts. Contracting is common for most processing vegetables in the United States, but processing tomatoes are unique in that a single bargaining association—the California Tomato Growers Association (CTGA)—represents the majority of growers. The CTGA negotiates with each of the nine processors and, as a result, farmers in California all receive approximately the same price in a given season, adjusted for quality and in some cases time of delivery. We see from the bottom line in Figure 4 that the price received by California growers has been relatively constant over the past ten years. Compared to most U.S. agricultural commodities, the price of processing tomatoes is incredibly stable. The coefficient of variation (cv) measures the variation of a variable in proportion to its mean, and for the grower price shown in Figure 4, the cv is only seven percent. The wholesale paste prices shown in Figure 4 have more variability over time—the cv is 13 percent. So it appears that the practice of contracting virtually the entire crop not only lowers the growers' price risk within a season, but also across seasons. Acreage appears to adjust from year to year to restore some balance to the market (if inventories deviate from the mean) but price fluctuations do not serve to fully equilibrate the market. Rather, this is apparently accomplished through grower-processor negotiations. Managing a market through non-price mechanisms is often a second best solution.

We now turn to the processor side of the equation. In Figure 5, we plot the estimated processing "gross margin" over ten years. This margin is the difference between what the processors receive for the paste and what they pay for field tomatoes. As alluded to earlier, gross margins were relatively high in the 1980s and early 1990s and this led to an expansion of processing facilities at that time. The estimated gross processing margin during recent years averaged 14 cents per pound of paste, lower than the margins during the golden years of the 1980s. The coefficient of variation for processor margins is 24 percent, almost double the volatility of the paste price, suggesting that processors absorb most of the price risk inherent in the market.

Figure 4. Wholesale Paste Price and Grower Price (cents/lb): Crop Years 1996 to 2005



Source: Wholesale paste price obtained from The Food Institute, for 55 gal. drums. USDA-NASS season average farm price, converted to paste equivalent, so it is the price of 6.25 pounds of field tomatoes, fob Processing Plant.

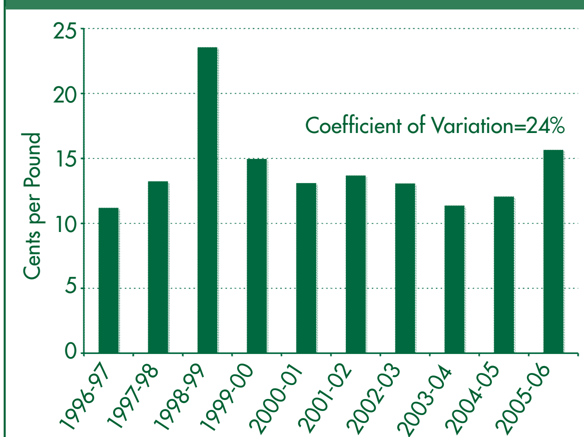
Global Market

The United States both exports and imports tomato paste, sauce, and other products. This is an example of what economists call intra-industry trade. Figure 6 shows that U.S. net exports (exports minus imports) are positive on balance and have risen since the lows achieved in the 1999-2000 season. Both tomato paste and sauce exports have risen over the last six years. In the most recent completed season (2005-06), exports of processed tomato products totaled 1.78 billion pounds (about 890,000 tons), farm weight equivalent. This means that slightly less than 10 percent of the crop is exported. Exports of tomato paste to Mexico have enjoyed strong growth together with those to Canada. These NAFTA partners now purchase about 65 percent of U.S. export sales of processed tomato products. At the same time exports to Japan have fallen, most likely due to competition from China. Nonetheless, Figure 6 demonstrates that international competition has not squeezed California out of the world market.

International trade in processed tomato products is influenced by a number of factors, including protective tariffs. The United States imposes an import tariff of 11.6 percent on tomato paste, which provides some protection to the California processors. At the same time, other importers (such as the EU) use tariffs and other barriers to protect tomato products from import competition and this limits market access for California exporters into certain countries.

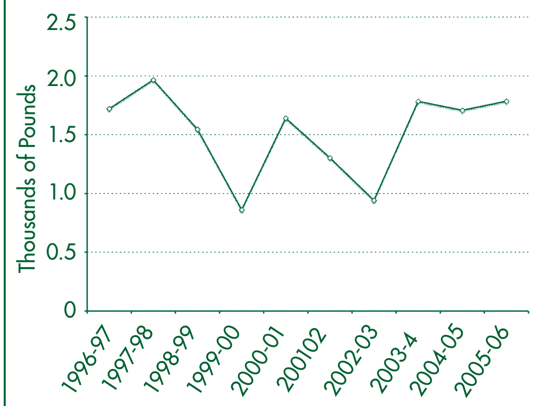
The concerns regarding increased international competition mentioned

Figure 5. Estimated Processor Gross Margin (cents/lb): Crop Years 1996 to 2005



Source: Wholesale paste price obtained from The Food Institute, for 55 gal. drums. USDA-NASS season average farm price using a conversion ratio of 6.25:1 tomatoes into paste.

Figure 6. Net Exports of U.S. Processed Tomatoes



Source: USDA, ERS

above were mostly based upon fears of China's rising production and exports. Like many sectors in California agriculture, the local processing tomato industry was and is concerned about developments in China and some view China as a threat to California's industry.

According to USDA information, China's paste production capacity has doubled in the last three years and processing tomato acreage has risen by about one-third. China is clearly on the move in this industry as in so many other areas. This year, China is expected to produce 4.5 million (short) tons of processed tomatoes, about 40 percent the size of the typical California crop. However, China's processed products are mostly exported, unlike in the case of California. The USDA estimated that China produced 1.65 billion pounds of paste in 2005-06, of which 70 percent was exported—almost double the volume of paste and sauce exported by the United States. Paste exports from China account for one-third of global exports.

China's future role in the global processed tomato market should not be underestimated. After economic reform in China 25 years ago, the USDA kept forecasting that China was going to become a huge importer of wheat and this has not yet happened. About 10 years ago, Lester Brown wrote a book that aimed to give us all a wake-up call with a well-publicized forecast that China was going to starve the world. He was wrong because he underestimated China's ability to increase food production. Will China flood the world with tomato paste, or will domestic consumption rise so rapidly in that country that it will start importing processed tomatoes? It is too early to tell. However, we do know that most of China's processing tomatoes are produced in Xinjiang and Inner Mongolia. These regions lie to the far Northwest in China and they are economically depressed compared to other parts of China. This is relevant because China's central government is committed to investing heavily in these relatively poor regions, as the road to economic development for the Northwest is through the production of exportable agricultural crops like processed tomatoes. The Northwest has fallen behind other parts of China in terms of economic growth.

The potential for expanded acreage in China and associated export growth is strongly affected by the dynamics of European Union (EU) farm policy, because the EU is the major destination for China's processed tomato exports. Italy is the number one market for China's tomato paste and puree exports, accounting for around 25 percent of China's offshore sales over the past three years. Most of the tomato product imports into Italy are reprocessed and re-exported. In 2004, Italy introduced new labeling regulations that favored domestic production but, so far, these regulations have not resulted in any significant reduction of imports from China. More importantly, EU tomato production subsidies (currently about $28 per short ton for within quota production) are expected to be lowered and "decoupled" from production. Subsidy reform in the EU could lead to production declines there, which is good news for the California industry. So any fear of China flooding the world market is to some extent buffered by developments in the EU where production might fall.

Summary

This article has examined the basic economics of the tomato processing industry in California in the context of the global market. We conclude that it is a market driven by domestic supply and demand fundamentals, with trade playing a minor role. This is partly because trade in tomato products has tariff protection in the United States and elsewhere. However, trade is not irrelevant because China is now a player in the export market for tomato paste and this has kept a lid on international prices. Policy reform in the EU could very well result in a rise of international prices if EU production drops along with lower subsidies.

Processed tomato inventories carried from one crop to the next are relatively high in California and these inventories tend to reduce any impact of supply shocks. Farm prices for processed tomatoes are exceptionally stable for an agricultural commodity. The processors' margin is much more volatile than farm prices, suggesting that processors carry much of the price risk in the market. Gross processor margins have remained relatively low in recent years, compared to the previous two decades. This is another reason why the industry has shown no signs of growth. But as the California industry goes forward, the fundamentals are strong and international demand may lead to an expansion of acreage and processing capacity.

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Why We Should Be Willing to Devote More Resources to Avoid Climate Change

Larry Karp

An important body of empirical models recommends modest efforts to reduce greenhouse gases. Although ostensibly scientific, these conclusions are actually largely driven by a value judgement. A recently developed, more flexible modeling approach produces dramatically different policy advice.

An important class of economic models imply that only modest efforts should be made to reduce greenhouse gas (GHG) emissions in the near term. These results can be interpreted as support for opinions, expressed by several prominent economists in the late 1990s and early 2000s, that the United States should reject the Kyoto Protocol. The models' mathematical foundation gives them the imprimatur of science; this prestige, and the lack of an empirical alternative, have increased the audience for the models' policy recommendations. Unfortunately, those recommendations are extremely sensitive to a parameter that reflects an ethical judgement rather than a "scientific" view: the long run discount rate. The choice of the value of this parameter has typically been constrained by technical limitations. A recent paper promotes a flexible alternative to the standard modeling framework. This alternative makes it possible to incorporate different (and arguably more reasonable) ethical judgements, which lead to significantly different policy advice: society should more aggressively seek to reduce GHG emissions.

Climate change policy is controversial largely because of the many uncertainties regarding the costs of reducing GHG emissions, and the costs of allowing GHG atmospheric concentrations to increase. Integrated Assessment Models (IAMs) address the big question, "What is the optimal trajectory for GHG emissions?" These models "integrate" economic and climate modules. The climate module describes how GHG emissions alter the atmospheric GHG concentration, and how this changing concentration alters climate. The economic module describes the economic costs of reducing GHGs emissions, and the economic costs associated with climate change. These models provide machinery to perform a cost-benefit analysis for different climate change policies, thus providing a means of selecting the optimal policy.

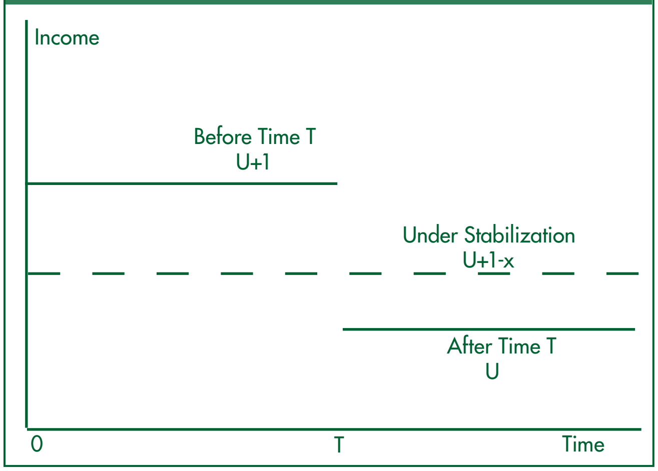
All components of these models are uncertain. Model builders do not claim that their model is "accurate"—an impossible standard—only that it is internally consistent. By incorporating the best estimates, or educated guesses, about the unknown parameters, the models might at least indicate the correct order of magnitude of the (unknown) optimal policy.

Many (but not all) economists think that significant reductions of GHG emissions will involve economic costs. These reductions would lead to lower future (not immediate) GHG concentrations, with correspondingly less climate change and lower future economic and environmental costs. Calculating the optimal climate change policy thus requires balancing current abatement costs with future benefits. Most cost-benefit analyses require this kind of comparison between current and future costs. However, the nature of the problem is more extreme in the case of climate change policy. In deciding whether it is worth building a bridge, for example, we need to compare the construction costs, which probably occur during the next five to ten years, with the stream of benefits that occur during the following several decades. Climate change policy, in contrast, requires comparing abatement costs which may occur over many decades, with the benefits (associated with reduced climate change) that may not begin for many decades but may last for centuries. With climate change policy, the time dimension of the tradeoff is vastly greater than for standard cost-benefit analyses of construction projects. Consequently, the assumption made about the willingness to exchange current costs for future benefits is much more important in climate change models.

We use the interest rate (also known as the discount rate) to compare dollar amounts at different points in time. For example, if the interest rate is five percent, a dollar one year from now is "equivalent" to $1/1.05 = 0.95$ dollars today; 0.95 is the "discount factor" corresponding to a five percent interest rate. A person who can borrow and lend at five percent would be willing to pay $0.95 today to avoid a one dollar payment in one year; this is the amount that would have to be invested today to return one dollar in one year. A person would pay only 60 cents today to avoid a payment of one dollar in ten years, and would pay less than one cent to avoid the one dollar payment in 50 years.

Models that evaluate social programs, such as bridge building or climate change policy, use a "social discount rate" rather than a private interest rate in order to be able to compare costs and benefits in different time periods. The following example shows why discounting is so important in climate change

Figure 1. Income Trajectory under BAU When Catastrophe Happens at time T and Trajectory under Stabilization

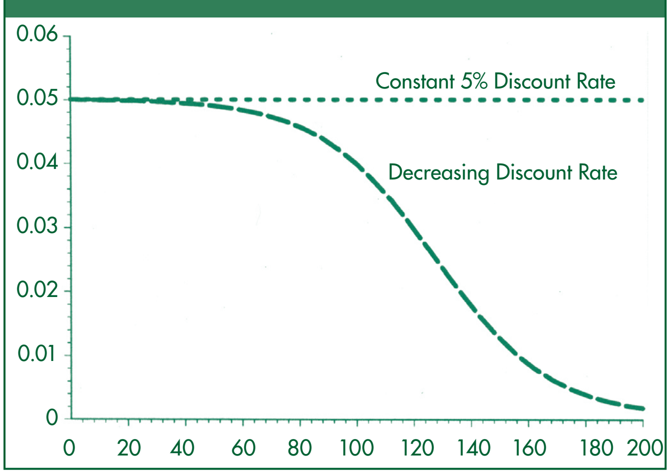


models. Suppose that under "business as usual" (BAU) there is a five percent chance of a catastrophe happening within a century. The catastrophe reduces yearly income by one unit (e.g., one hundred billion dollars); this one unit is the "value-at-risk." Prior to the catastrophe, society has the yearly income of U+1, and after the catastrophe occurs, the amount drops to U. The solid lines in Figure 1 shows the trajectory of income under BAU if the random event happens at time T. Suppose that society has the opportunity of pursuing a policy called "stabilization" that reduces yearly income by x and also eliminates the risk of the catastrophe. The dashed line in the figure shows the trajectory of income under this policy. Given a five percent yearly discount rate, and a five percent chance of the catastrophe occurring within a century, society would be willing to pay no more than one percent of the value-at-risk.

In the case of climate change where inertia is important, current actions could alter future but not current risk. By assuming that the policy has an immediate effect on the risk, this example actually overstates the amount that society would be willing to spend.

The message from this example is that if we use a constant discount rate with a "typical" magnitude, e.g., between three percent and seven percent, then society should not be willing to spend much to reduce the risk of low-probability events. "Low-probability events" are those that are not likely to occur in the near future; such events may be very likely to occur in the distant future. Discounting at a non-negligible rate makes the distant future almost irrelevant to policy today. In other words, the conclusion that society should not be willing to pay much to reduce the risk of a low-probability event is practically guaranteed by the assumption of constant discounting. That assumption is not grounded in science; rather, it reflects a value judgement that the distant future is unimportant.

Figure 2. Constant Five Percent Discount Rate and Decreasing Discount Rate



Empirical evidence supports the use (in cost-benefit analyses) of a non-negligible discount rate for the next two or three decades. There is no empirical or theoretical reason why the very long-run discount rate should be anything like the short-run rate. For example, the statement that we have a five percent short-run social discount rate means that society is willing to give up $1.65 ten years from now in exchange for an additional one dollar today. Empirical evidence suggests that this is how we behave; therefore, economic models that reflect society's preferences should incorporate the willingness to make this kind of trade-off. This evidence says nothing about the trade-off that we would be willing to make between two points in time in the distant future. Consider the question "How much are we willing to take away from people living 210 years from now in order to give one extra dollar to people living 200 years from now?" Climate change modelers (implicitly) answer this kind of question in choosing values for the long-run discount rate. A plausible response is that we have no particular reason for preferring the welfare of people living 200 years from now to people living 210 years for now—both groups are strangers to us—so we would be willing to take only one dollar from the latter group in order to give one dollar to the former. If we accept this view, it means that our long-run discount rate approaches zero.

Figure 2 shows the graph of a constant discount rate at five percent, and a decreasing discount rate that begins at five percent and gradually declines to a number close to zero. These two discount rates are nearly the same for the first 80 years, but then they begin to diverge. Figure 3 shows the discounted value of one dollar, corresponding to these two rates beyond 75 years. A point on the curve tells us how much we would pay today to avoid a one dollar cost at some time in the future. For example, under constant discounting at five percent, we would pay slightly more than one-half of one cent (0.67 cents) today to avoid a one dollar cost one hundred years from now, and under the declining discount rate we would pay 0.84 cents (an increase of about 25 percent). The point of the two graphs is that these two models of discounting—constant and declining—imply similar trade-offs during the first century.

Despite this similarity, the two discount rates imply very different attitudes to the future. For example, suppose there is a value-at-risk of one unit (e.g., $100 billion) and society has a choice of decreasing this amount by 10 percent in perpetuity, or having no decrease for the first T years and eliminating the entire amount thereafter. Under constant discounting, society is willing to forgo the entire amount after 46 years in order to avoid the 10 percent reduction that begins immediately. Under the decreasing discount rate shown above, the cutoff date moves to 840 years. Even though the two discount rates are very similar for about a century, the model of decreasing discount rate values future welfare much more highly, compared to the model of constant discounting.

Because of this difference in the value given to the future, the two models lead to very different policies to deal with climate change. We noted above that society is not willing to spend much to avoid low-probability catastrophic events under constant discounting. With a decreasing discount rate, it may be optimal to spend a significant amount to reduce or eliminate risk.

We currently are not able to measure the risks of catastrophic climate change. In the absence of such measures, we cannot construct genuinely empirical models of catastrophic risk. However, examples give us a sense of how we should respond to these risks. Figure 4 shows graphs of a (hypothetical) example of the risk of occurrence (of a catastrophic event) under two policies: stabilization and Business as Usual (BAU). The risks begin at the same low level, and increase under both policies, but they increase much more rapidly under BAU. For this example the risk of occurrence within a century is one percent under stabilization, and 17 percent under BAU.

Suppose, as above, that if the event occurs it reduces (in perpetuity) society's annual income by one unit (e.g., $100 billion). Under constant discounting, society would be willing to spend (each year) about one percent of the value-at-risk in order to follow the stabilization path, rather than the BAU path; under the decreasing discount rate, society is willing to spend about 18 percent of the value-at-risk to follow stabilization.

This example, and others like it, cannot provide a precise guide for policy advice. They do, however, illustrate an important lesson. Climate change models that use (non-negligible) constant discount rates effectively assume that we should not undertake significant efforts to reduce the risk of low-probability catastrophic events. Since there is no scientific basis for the use of these long-run discount rates, this conclusion is essentially an ethical judgement, not a scientific one. A model that values the future more highly recommends a more aggressive policy to reduce GHG emissions.

These points are well understood by climate change modelers. The widespread use of constant social discount rates for climate change models is largely due to a technical problem that arises in models with non-constant discounting (the "time consistency problem"). The paper by Karp and Tsur shows how to overcome this technical problem, making it possible to explore more fully climate change models that use a "typical" short-run discount rate, and much smaller long-run rates. This alternative gives more weight to the welfare of future generations, compared to standard integrated assessment models.

Figure 3. Discount Factor under Five Percent Discount Rate and Decreasing Discount Rate

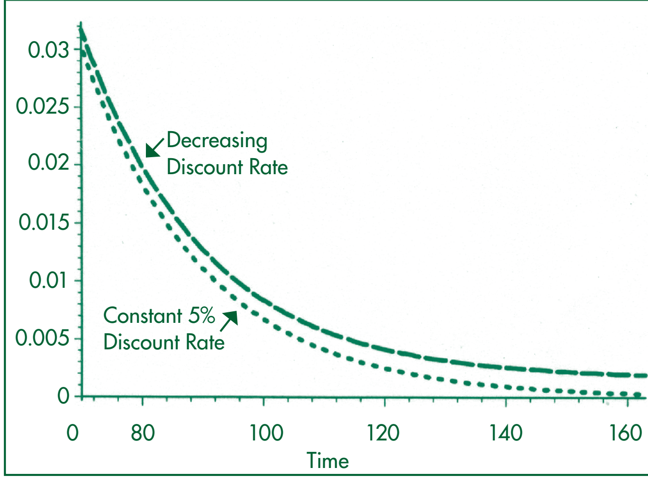
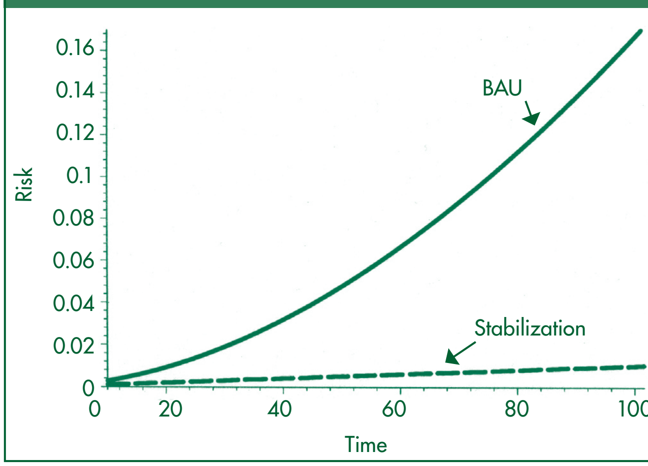


Figure 4. Probablility of Catastrophic Event Occuring on or before Time *t*, under BAU and Stabilization



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For further information, the author recommends

Climate Policy When the Distant Future Matters: Catastrophic Events with Hyperbolic Discounting," http://are.berkeley.edu/~karp/.

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