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Food Safety and Defense Risks in U.S.-Mexico Produce Trade

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The demand for Mexican-grown fruits and vegetables in the United States is increasing because off-season demand is not being met by domestic production. Approximately 6.2 billion pounds of fresh fruits and vegetables were imported from Mexico to the United States in 2005, 6.49 billion pounds in 2006 and 7.24 billion pounds in 2007 (USDA-FAS, 2008). The large volume of fresh produce imports introduces food safety and food defense risks all along the supply chain. Food safety policy has conventionally addressed prevention of unintentional contamination of food and economic adulteration (Acheson, 2007). Food defense policy reduces the likelihood or impact of intentional contamination to cause harm. These could include a wide range of actors from disgruntled employees to international terrorists. In this article, we evaluate the use of intelligent inspection systems to mitigate both types of risks.

The Food and Drug Administration (FDA) inspects about 1% of the imported foods it regulates at the border due to resource limitations, down from 8% in 1992 when imports were far less common (U.S. CBP, 2008). Ideally, an inspection procedure should protect food imports from outbreaks of food-borne illnesses that may cause recalls. However, due to limited resources, high volumes and border facility limitations, it is impossible to inspect all produce at the Port of Entry (POE) with a random inspection system, which may require the selection of representative samples. Intelligent systems could alleviate some of these challenges and improve the safety of imported foods.

Science-based intelligent inspection systems have been used in a variety of fields in engineering and manufacturing. The general idea is to develop highly adaptive inspection methodologies, which over time can incorporate on-line sensors. For example, the COOLTRAX (http://www.cooltrax.com) system provides real time "journey based" data on temperature, vibration and geographical position linked to an internet data base that can be accessed by multiple entities and agencies. Information on produce shipments can be shared and used to target inspection resources to high risk cargos. If a truck is diverted from its normal route and tampered with, causing temperature changes that may result in higher levels of produce spoilage and pathogen growth, that load can be designated as a high risk cargo and inspected accordingly. This can also address other problems related to drug trafficking with produce shipments.

In this article we use a threat, vulnerability and consequence prevention (TVCP) model to evaluate the effectiveness of current inspection procedures and tools. We then discuss how on-going preliminary findings on the use of intelligent systems support their use to improve the safety of imported produce from Mexico. Intelligent systems could address issues related to information sharing, cost-effective use of limited resources, and mitigating potential market failure problems in food imports.

Food Safety/Defense Risks and Market Failure

We now know that food safety/defense failures can cause complete market failure. Historically, firms may have considered supply chain risks and protection in the context of the potential threats and disruptions to their own operations. However, the interconnectedness of firms, products and transportation infrastructure in high-speed global supply chains multiplies the potential costs of these risks. When limited inspection resources are not efficiently distributed, market failure may arise from negative externalities or from the failure of public agencies to provide the minimum acceptable level of safety. Negative externalities may occur when some participants in the supply chain implement a food safety measure but yet are impacted by a food recall due to problems caused by others who have not implemented similar recommended measures. When inspection systems fail to mitigate illness outbreaks from food pathogens, then food recalls and illness outbreaks can be attributed to a government failure of the responsible domestic or international agencies.

Recent outbreaks from international sources are consequences of market failure. These examples include the 2008 *Salmonella enterica* outbreak of fresh jalapeño and serrano peppers from Mexico which caused at least 1,329 cases of *salmonellosis* food poisoning in 43 states throughout the United States, 257 hospitalizations and two deaths; the 2003 green onion *Hepatitis A* outbreak with over 650 cases in four states and four deaths (Clark, 2005); and the loss of the cantaloupe market in the United States for most growers in Mexico following repeated outbreaks of *Salmonella* in 1997 and 2000. Chalk (2003) notes that in the last century, there were 12 documented cases where pathogenic agents were used to infect livestock or contaminate food intentionally.

Inspection by government agencies is a major strategy to minimize outbreaks and resolve market failure problems. The U.S. Department of Agriculture can inspect produce at foreign farms or in foreign country packing and processing facilities. In this inspection program, however, their focus is more on ensuring compliance with quality and grading standards rather than pathogen testing. The Food and Drug Administration conducts pathogen testing at the Port-of-Entry at the same time as various other state and federal agencies which are charged with providing protections from various other problems. The involvement of multiple agencies responsible to ensure the safety of imported foods creates additional administrative challenges like information sharing and identifying high risk imports from multiple risk factors such as location, pest, pathogens, and chemical agents. While TVCP is only a public policy instrument, it is helpful to explore how it is a response to fundamental economic problems in the industry, addressing structural causes of market failure that are pervasive in supply chains of all types. Adoption of intelligent systems may allow more efficient use of limited resources and minimize market failure risk from food imports.

Evaluating Import Safety with the TVCP Framework

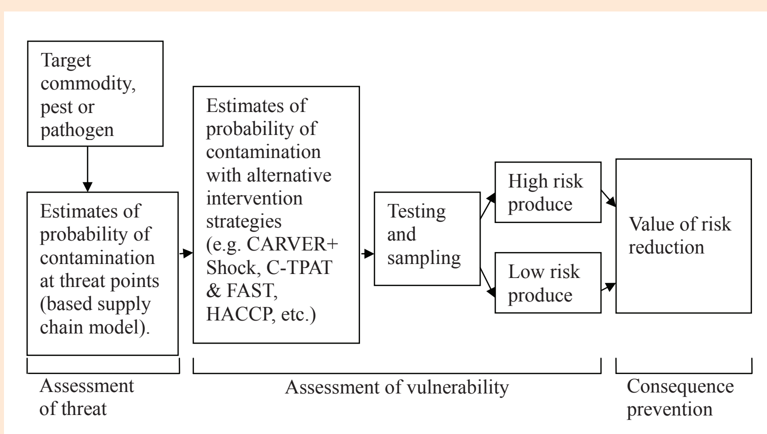
The Threat, Vulnerability and Consequence Prevention (TVCP) framework is an extension of the Threat, Vulnerability and Consequence (TVC) analysis used extensively in event modeling by the U.S. Navy, Department of Homeland Security, and the Environmental Protection Agency (Cox, 2008). Threats are weak links along the supply chain. Vulnerabilities are those threats that could not be eliminated with alternative risk mitigation strategies. Consequence prevention puts the emphasis on prevention or risk premiums industry is willing to pay for alternative risk mitigation technologies. Several important risk analyses now utilize the TVC framework in setting priorities for protecting U.S. infrastructures against terrorist attacks based on the formula: $Risk = Threat \times Vulnerability \times Consequence$.

One distinction between the TVCP and TVC analyses is that the former focuses on risk mitigating preventive measures that allow for resource allocation while the later focuses on aggregate consequence in the event of a food safety recall and food terrorism attack. The TVCP can be structured as a *two-level, or multiple-level, hierarchical optimization model* to evaluate risk mitigation alternatives. In such two-level optimization models, participants along the supply chain can determine in level one whether or not to test for pathogens or chemical agents and in level two determine the optimal sampling intensity or sample size based on alternative capacity limitations. Figure 1 presents a schematic representation of the TVCP framework and the accompanying box defines the terminology used. This extension of the TVC is more appropriate in analyzing and mitigating potential food safety and food defense risks.

Assessment of Threat and Vulnerability

Currently, the Nogales Port-of-Entry (POE) uses a risk-based sampling process for selecting high and low risk samples. However, the level of inspection for each commodity is based on analysis of crop pest risks. Food safety/food defense risk factors

Figure 1. Conceptual TVCP Framework, Hu, 2008.



are not explicitly incorporated in the current risk based sampling process. Other public and private sector initiatives currently used at the Nogales POE to categorize commodities into high and low risks and to address food safety and food terrorism threats and vulnerabilities have been developed in recent years by USDA, FDA and the Department of Homeland Security. Examples are the CARVER plus Shock approach, the Custom Trade Partnership against Terrorism (C-TPAT) and Fast and Secure Trade (FAST) (see Figure 2). These tools have broader applications not related solely to agriculture and food trade.

We conducted a study that customized the U.S. Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS) "Food Safety/ Defense Plan Assessment Survey" to identify the threats and vulnerability along the U.S.-Mexico produce supply chain. The survey had six major sections to elicit information on the gaps in food protection for each participant along the international food supply chain. Data was collected on 1) CARVER plus Shock, C-TPAT and FAST usage; 2) type and volume of commodities grown, processed, and distributed; 3) availability and usage of security measures (personnel, inside plant, outside plant, water, ingredient and chemical storage security); 4) pathogen and chemical testing; 5) knowledge and perception of risks; and 6) demographic factors. The survey was extensively reviewed, pilot tested, and translated into Spanish to ensure content validity. A random sample was used to collect the data representing all participants along the supply chain. Data were collected from 403 growers and grower employees, 84 truckers and trucker employees, and 55 distributors and packers. Six major commodities were examined: peppers, watermelons, tomatoes, green onions, broccoli, and oranges.

Statistical and stochastic simulation analyses were used to assess the risk each participant poses to the supply chain and the vulnerability of the system. Threat or risk along the supply chain was measured by whether or not participants were C-TPAT/FAST certified or to what degree they have implemented components of these programs. The simulation model was used to determine vulnerability or optimal testing and sampling intensity that could minimize food safety and defense threats. The model was used to determine whether or not to test at a particular location, and if so, at what intensity or sample size.

Results revealed that most participants were not C-TPAT/FAST certified but they do implement components of these programs, indicating moderate risk levels or threats. Trucking constitutes the greatest vulnerability to not implementing components of C-TPAT/FAST with 50.62% threat probability. Grower/ packers follow with 29.62% probability and finally distributors have the lowest threat probability with 19.76%. This indicates that targeting intelligent inspection systems on the trucking segment could significantly improve food protection for the U.S.-Mexico produce supply chain. For each participant, personnel security

Figure 2. Description of CARVER + Shock, C-TPAT, and FAST

Program & Definition	Description
CARVER plus Shock	CARVER: Criticality—measures public health and economic impacts of a system attack; Accessibility—ability to physically access protected assets (target); Recuperability—ability of the system (channel) to recover from an attack; Vulnerability – ease of accomplishing an attack; Effect —amount of direct loss from an attack as measured by loss in production; and Reconcilability – ease of identifying the target. In addition, the modified CARVER tool evaluates a seventh attribute, the combined health, economic, and psychological impacts of an attack, or the Shock attributes of a terrorist event upon the targeted assets.
C-TPAT	The Customs-Trade Partnership Against Terrorism (C-TPAT) is a joint voluntary government-business initiative to build cooperative relationships that strengthen and improve overall international supply chain operations and U.S. border security (U.S. CBP, 2008). Through this initiative, Customs and Border Protection (CBP) asks businesses to ensure the integrity of their security practices and communicate and verify the security guidelines of their business partners within the supply chain.
FAST	FAST allows U.S./Canada and U.S./Mexico partnering importers expedited release for qualifying commercial shipments" (U.S. CBP, 2008). At the southern border, the FAST program is a voluntary initiative between the U.S. and Mexico designed to ensure security and safety while enhancing the economic prosperity of both countries. The initial phase of FAST for United States and Mexico bound commercial shipments began on Sept. 27, 2003 at the Port of El Paso, Texas. By Aug. 31, 2006, the FAST program was expanded to 14 POEs on the southern border. To be eligible for joining the FAST program, participants such as drivers, carriers, importers and southern border manufacturers are asked to submit an application, a C-TPAT member agreement, and undergo a security profile assessment dependent upon their role in the C-TPAT. For instance, the vehicle driver only needs to submit the application; however, the carrier has to submit a C-TPAT Highway Carrier agreement with the application to prove that the firm is a certified C-TPAT partner. An importer or southern border manufacturer has to submit the "Importer Security Profile" or "Supply Chain Security Profile" form to supplement the other required documents. The C-TPAT/FAST programs qualify those known low-risk participants for receiving expedited border processing access.

(CARVER + Shock Primer, 2009)

and inside plant security contributed the most variability or threat while outside plant and storage security followed with less threat probability. For inside plant security and personnel security, not many firms perform background checks of their employees and most do not have cameras located in processing and storage areas. Most participants do have facilities that are secured or have outside plant security to prevent entry by unauthorized persons, hence lowering threat. Also, visitors are not allowed easy access to produce storage areas.

Consequence Prevention

The simulation model used to assess vulnerability was used simultaneously to derive the risk premium (expected net returns minus a certainty equivalent return) or value of risk reduction from C-TPAT/FAST usage for each low or high risk produce. The use of net returns, to derive the risk premium, enables us to evaluate cost-effectiveness of the C-TPAT/FAST programs. The simulation model was built using data from the survey and additional data on shipment flows and prices for fresh fruits and vegetables from 1998 to 2007 obtained from the USDA's Agricultural Marketing Service *Fruit and Vegetable Market News*. Lot size, or the truck trailer compartment capacity, is assumed to be 40,000 lbs. per shipment delivering fresh produce across the U.S.-Mexico border.

Our results show that in order to appropriately mitigate food safety and defense risks, USDA's Food Safety Inspection Service should be testing almost 24% of peppers, 44% of watermelons, and 44.27% of tomatoes compared to inspecting less than 1% of commodities based on crop pest risk. It should also be noted that even though all trucks containing products that post a high risk for crop pests are currently inspected, only 2%-3% of the boxes within each truck are inspected. Further, foods that have experienced food safety outbreaks and recalls in recent years like peppers and green onions are not viewed as high risk under the current system's focus on crop pest risks.

However, simply increasing or decreasing the total sample size without considering time and facility limitations may not be an optimal solution to the inspection problem. With available resources, it will be impossible to inspect 24% or 44% of imports as results indicate. Intelligent systems on trucks to provide safety information from "journey based" data could be more effective, given that trucking presents the greatest source of food defense risk for produce imported from Mexico.

Intelligent Systems and Cost-Effectiveness of Inspection Processes

To determine whether intelligent systems could be more effective at detecting food defense risks and to test their usefulness in evaluating food safety risks, we installed three COOLTRAX and ACR SmartButton units on trucks carrying fresh fruits and vegetables from Mexico to the United States. Each unit cost approximately $880, including $680 for the unit and $200 for installation and monthly data access. Throughout the journey from farm to the border, the units sent real-time data on temperature, location, and vibration to a secured location on the internet. The data can be used to reevaluate the consequence prevention model. The units also capture data pertinent to the inspection decision problems faced by the federal agents at the U.S. POE. The collected data can also be used to evaluate performance of the supply chain, allowing improvement of delivery times and minimizing temperature fluctuations that may encourage pathogen growth. Information gained from intelligent systems can also be used by government inspectors to efficiently allocate limited resources to higher risks cargos compared to inefficient allocation that may be based on increasing random sample size for inspection.

Preliminary results from analysis of the journey data indicate that intelligent systems could minimize the cost of two types of errors. The first type of error occurs when a truck is declared "safe" and allowed to proceed into the United States when, in fact, its contents are not safe. This type of error is a kind of market failure risk, called buyer risk. Such "buyer risks" resulted in last summers' outbreaks of *Salmonellosis* associated with jalapeno and serano peppers from Mexico. The second type of error occurs when a truck's load is declared "not-safe" and authorities impede its movement into the United States when in fact the contents are safe. This second type of inspection error creates market failure risks called seller risk. Several false alarms occur during inspection at the border causing millions of dollars of losses to participants along the U.S.-Mexico produce supply chain. An example of a false alarm is the jalapeño peppers outbreak that was first attributed to tomatoes. Preliminary results suggest that a decrease in food protection risks, with the use of intelligent systems, will lead to a decrease in both buyer and seller risks and improve the cost-effectiveness of the inspection process.

Policy Implications

Policies leaning towards increasing sample size and the number of microbial tests will not optimally improve the safety of imported produce. Inspecting every container arriving at U.S.-Mexico POEs would be neither physically possible nor cost-effective. The United States cannot build border facilities that will enable the inspection of all produce shipments or the sample sizes determined in our analysis, due to resource limitations and facility constraints.

Real-time intelligent technologies offer the promise of more efficient monitoring of safety in the U.S.-Mexico produce supply chain. This monitoring could be useful to both private industry and government agencies charged with assuring the safety of these imports into the United States. Further analysis is required to assess optimal deployment of these technologies, but our research indicates they are technologically effective. Participants along the U.S.-Mexico produce supply chain should be encouraged to explore obtaining C-TPAT/FAST certification or voluntarily implement portions of these programs in combination with real-time intelligent technologies. These systems will reduce buyer and seller risks and appear to be more cost-effective in preventing food safety and defense failures, compared to current inspection systems. Real-time "journey based" information could also be shared by multiple agencies and partners, reducing the cost of information gathering. If extended to distributors and retail facilities in the United States the real-time database could also be used for traceability, reducing market failure cost of delay tracking or false alarm. Keeping a database on origin and trajectory of products might have avoided implicating tomatoes as the initial cause of the 2008 *Salmonella* Saintpaul outbreak.

One major limitation of the current inspection system is that requirements in Mexico are different from those in the United States. Even within the United States, local, state, and federal inspection agencies face significant challenges with information gathering and sharing. Research should be encouraged to advance the science and security of real-time intelligent systems to enable such systems to provide reliable data on microbial and chemical contamination signals. This approach might provide a more comprehensive solution to improving the safety of imported produce.

For More Information

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