New Generation of Standards and Potential Impacts of Food Borne Illness Incidences on Market Movements and Prices of Fresh Produce in the United States

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Executive Summary

Historically the United States was perceived to have the safest food supply in the world. While, in fact, this may still be true, a number of incidents have led to questions regarding the safety of the U.S. food supply. Three case studies were analyzed to assess the potential impacts of food safety outbreaks on domestic shipments, imports and prices of the produce industry: the cantaloupe outbreak of March-April 2008, the spinach outbreak of September 2006, and the tomato outbreak of June-July 2008. Data determined historical decompositions were conducted to provide a weekly picture of domestic shipment, import and price fluctuation transmissions. The empirical analysis based on a vector autoregression (VAR) model showed differences in the results depending on the source of the outbreak (domestic versus imported). Cantaloupe innovations are connected with information flows among domestic shipments, imports and prices, but the direction of causality is not certain. Spinach innovations are contemporaneously independent. Contemporaneous innovations in tomatoes imports were caused by innovations in prices and domestic shipments. Historical decomposition of each price series showed similar results for cantaloupes and tomatoes; with information prior to the illness outbreaks actual prices were higher than forecasted prices most of the time. In spinach there was an overall negative response in price, with actual prices below forecasted prices. Most of this negative information on spinach arises in the price information itself, suggesting that a drop in consumer demand might be behind the fall in spinach prices.

The short-term farm level impacts of the cantaloupe, spinach, and tomato food outbreaks to their industry was estimated by forecasting domestic shipments, imports and prices using only information known prior to the food outbreaks. The difference between forecasted variables and actual values is attributed to information arising from the outbreaks. It was estimated that the short-term farm level losses for US spinach were over $8 million; US tomato farm losses were $25 million; and cantaloupe losses were estimated at $5.8 million for the domestic market, and $29.5 million for imports.

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Abstract

This study investigates the potential impacts of food safety outbreaks on domestic shipments, imports and prices of the produce industry. Three case studies were analyzed to assess these potential impacts: the cantaloupe outbreak of March-April 2008, the spinach outbreak of September 2006, and the tomato outbreak of June-July 2008. Data determined historical decompositions were conducted to provide a weekly picture of domestic shipment, import and price fluctuation transmissions. The empirical analysis based on a vector autoregression (VAR) model showed differences in the results depending on the source of the outbreak (domestic versus imported).

Key Words: food safety, outbreaks, historical decomposition, directed acyclic graphs, fresh produce.

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Introduction

Historically the United States was perceived to have the safest food supply in the world. While, in fact, this may still be true, a number of incidents have led to questions regarding the safety of the U.S. food supply. Aside from the safety of the products they produce, fresh fruit and vegetable growers face many challenges. These include water availability for irrigation, increased energy and chemical costs, pest control, increased competition from globally sourced products, and the availability and cost of labor. With these many challenges, questions arise as to how much producers can afford to spend to assure the safety of their product? Put differently, what is the cost of not effectively controlling product safety? The following three case examples provide insight into the answers to these questions.

Consumers react to the news of a food safety alert by immediately changing their buying patterns and reducing consumption of the affected products. Since the initial reports of an outbreak may be indecisive as to the scope and origin of the problem, consumption/product demand may be affected nationally and even internationally. This shorter–term impact may actually shut down market movement until the source of the outbreak becomes clear by product, by the specific pathogen, by the source of the pathogen, and even by the handler and farm on which the product was produced. This may take several days or weeks. The reduction in sales depends on the severity of the outbreak, in terms of the number of people affected, number of deaths, regional scope, and the type of products and its origin. Even after the source is identified there are potential longer-term impacts on consumption and the entire supply chain including issues such as legal liability from the incident, which may occur over a period of several months or years after the outbreak. This paper will study both, the contemporaneous and lagged effects of food borne illness in the fresh produce industry, and the length of time required to return to normal levels and the associated producer costs of the outbreaks.

Three case studies will be used to assess the potential impacts of outbreaks on product shipments and prices. Specifically, we analyzed the spinach outbreak of September, 2006; the cantaloupe outbreak of March-April, 2008; and the tomato outbreak of June-July 2008. The data used in this study are weekly domestic shipments and imports, and average prices for domestic production and imports of spinach, cantaloupes, and tomatoes from the Agricultural Marketing Service (AMS), of the U.S. Department of Agriculture for the periods around the outbreaks (USDA, 2007). The prices are average weekly prices for all shipments, including national production and imports. Prices are expressed in dollars per one-half cartons of cantaloupes (40 pounds), carton of tomatoes (25 pounds), and a carton of 24s bunches of spinach (20 pounds).

On September 13, 2006 the Food and Drug Administration (FDA) issued a warning of a multi-state Escherichia coli (E. Coli) O157:H7 outbreak associated with the consumption of bagged spinach (FDA, 2006). The first reports were confirmed by several states on bagged spinach having a “best if used by” date of August 30, 2006. By the time the outbreak was contained 227 people had become ill across the United States, 104 had been hospitalized, 31 had developed serious complications from hemolytic-uremic syndrome and 3 had died. An all-clear lifting of the warning alert was issued by FDA, although by about November 1, 2008, the sources of the contamination had been clearly identified and measures were being taken to assure that the incident was under control (FDA, 2008).

On March 22, 2008, the FDA issued a warning alert of salmonella food poisoning associated with cantaloupe. The alert spanned 16 states and several Canadian provinces. According to the FDA, since January 2008, cantaloupes imported from Honduras, Central America, left 50 people ill with salmonella poisoning. While no deaths were reported, 14 people required hospitalization. In their warning, the FDA linked the outbreak to a single company in Honduras.

On June 3, 2008 the FDA alerted consumers in New Mexico and Texas that a salmonella outbreak appeared to be linked to consumption of certain types of raw red tomatoes and products containing raw red tomatoes. Although the official alert was on June 3, the Centers for Disease Controls (CDC) and FDA notifications indicated that reported cases in New Mexico extended back to April 16, 2008. From early in the period, the prime suspected sources were tomatoes grown in Florida and Mexico. The warning alert was lifted on July 17, 2008, when it was determined that Jalapeño and Serrano peppers from Mexico were the source of the contamination.

These outbreaks are not unique. According to the CDC, more than 76 million people are affected and 5,000 die as a result of food poisoning every year. The most common food-borne illnesses are campylobacter, salmonella and E. Coli. Over the past 12 years, 22 leafy green E. Coli O157:H7 outbreaks have been identified. All 22 indicated a California source of the leafy greens. Since the mid-1990's foodborne illness outbreaks have occurred that were linked to raspberries, green onions, peppers, sprouts, and strawberries. In part as a reaction to these events increased efforts to enhance food safety have been undertaken by the government and associated industries groups. Efforts have focused on increased scrutiny of imported products and the improvement in domestic standards.

The main objective of this paper is to study the contemporaneous and lagged effects of food borne ill incidence on market movements and prices of fresh produce in the US by using historical decomposition analysis of the dates around the neighborhood of the outbreaks. This paper will also evaluate whether these effects differ according to the source of the outbreak (domestic versus imports) by analyzing three different case studies with a different source of the outbreak. Finally, the farm level costs associated with these outbreaks will be calculated.

Methodology

The working hypothesis is tested empirically using a time series econometric model. Specifically, the model explores how information is communicated across the three variables, price, imports and shipments for each product in a neighborhood of the aforementioned food events. The empirical analysis is based on a vector autoregression (VAR) model in which directed acyclic graphs are used to sort-out causal flows of price information in contemporaneous time. Let Xt denote a vector that includes the weekly prices, imports and shipments of each vegetable product:

(1) $$X_t = \begin{pmatrix} P_t \\ I_t \\ S_t \end{pmatrix}$$

where t is an index of time observed. Under fairly general conditions the dynamic correlation structure between these variables can be summarized as a structural vector autoregression. The structural VAR representing a $N \times 1$ vector of variables X_t can be written as:

(2) $$\Phi_0 X_t - \sum_{k=1}^{K} \Phi_i X_{t-k} = \varepsilon_t$$

Here contemporaneous and lagged values of observational measures on *X* at periods t-k, k = 0, 1, …, K are mapped into the white noise innovation term ε_t , where $Cov(\varepsilon_t) = \Omega$ and M_i , i=0, 1, …, K are square autoregressive matrices of order 3. The innovations ε_t are structural as they represent new information arising in each element of the X vector at time t. Under general conditions permitting matrix inversion an equivalent form exists as:

(3) $$X_t - \Phi_0^{-1}\Phi_1 X_{t-1} - \cdots - \Phi_0^{-1}\Phi_k X_{t-k} = \Phi_0^{-1}\varepsilon_t \,.$$

The reduced form (non-structural) VAR is written in similar form as:

(4) $$X_t - \Pi_1 X_{t-1} + \cdots + \Pi_k X_{t-k} = u_t \,;$$

where $\Pi_h = \Phi_0^{-1}\Phi_h$ for k = 1, …, K and $u_t = \Phi_0^{-1}\varepsilon_t$. The reduced form innovations (u_t) are "mongrel" or combinations of the structural innovations ε_t. It follows thus that $Cov(u_t) = \Sigma = \Phi_0^{-1}\Omega \left(\Phi_0^{-1}\right)$.

While the reduced form VAR has been championed as "atheoretic", the key to modeling structural VARs is proper identification of the matrix A_0. Bernanke (1986) and Sims (1986) used prior theory to achieve such identification. More recent work follows that of Swanson and Granger (1997) to use the causal pattern exhibited by observed innovations $\hat{u}_t$ to identify $M_{0.}$ This paper uses the machine learning algorithms of Spirtes, Glymour and Scheines (2000) as applied earlier in Bessler and Akleman (1998) and Hoover (2005) to achieve structural identification.

The dynamic response patterns summarized by a VAR are difficult to interpret (Sims, 1980; Swanson and Granger, 1997). The dynamic price relationships can be best summarized through the moving average representation. Given the estimated form of equation (2), we can algebraically re-express equation (4) as a levels VAR. We can then solve for its moving average representation, where the vector X_t is written as a function of the infinite sum of past innovations:

(5) $$X_t = \sum_{i=0}^{\infty} \Theta_i u_{t-i}$$

where G_i is a 3x3 matrix of moving average parameters, which map historical innovations at lag *i* into the current position of the vector *X*.[1] Notice 1_0 is not zero here as we use directed graph structures on the observed innovations from the reduced form VAR to translate these nonstructural innovations to structural innovations as suggested first by Swanson and Granger (1997).

A directed graph is a picture representing the causal flow among a set of variables. Lines with arrowheads are used to represent flows. For instance, A→ B indicates that variable A causes variable B. A line connecting two variables, C – D, indicates that C and D are connected by information flow but it's not certain whether C causes D or vice versa. Observed innovations from an estimated form of equation (4) are modeled as a directed acyclic graph for each produce commodity. The fundamental idea that enables detection of the direction of causal flow to a set of (observational) variables is the screening-off phenomena and its more formal representation as d-separation (Pearl, 2000). For three variables A, B and C, if we have variable A as a common cause of B and C so that B←A→C, then the unconditional association between B and C will be non-zero, as both have a common cause in A (this diagram is labeled a causal fork (Pearl 2000)). If we measure association (linear association by correlation) then B and C will have a non-zero correlation. However, if we condition on A, the partial correlation between B and C (given knowledge of A) will be zero. Knowledge of the common cause (A) "screens-off" association between its effects (B and C).

On the other hand, say variables D, E, and F such that D→E←F. Here E is a common effect of D and F (this diagram is labeled a causal inverted fork (Pearl 2000)). D and F will have no association (zero correlation if constrained to linear association); however, if conditioned on E, the association between D and F is non-zero (the partial correlation between D and F, given knowledge of E is non-zero). Knowledge of the common effect does not "screen-off" association between its causes. And if variables A, B and C forming a causal chain, A→B→ C, the unconditional association (correlation) between A and C will be non-zero, but the conditional correlation between A and C, given knowledge of B will be zero.

Spirtes, Glymour and Scheines (2000) and Pearl (2000) present algorithms with similar structures and outputs for inference on directed acyclic graphs from observational data. The former is labeled PC algorithm, embedded in the software TETRAD II and III (see the offering at http://www.phil.cmu.edu/projects/tetrad/ and Scheines *et al*., 1996) and described in Spirtes, Glymour and Scheines (2000); the latter is IC algorithm presented in Pearl (2000, pp.50-51). PC algorithm has been studied extensively in Monte Carlo simulations in Spirtes, Glymour and Scheines (2000) and Demiralp and Hoover (2003). The algorithm may make mistakes of two types: edge inclusion or exclusion and edge direction (orientation); the latter appears to be more likely than the former. Spirtes, Glymour and Scheines write: "In order of the methods to converge to correct decisions with probability 1, the significance level used in making decisions should decrease as the

[1] While one can actually derive the first *n* terms of equation (4) analytically, we almost always allow the computer to do this following the zero-one simulation as described in Sims (1980).

sample size increases and the use of higher significance levels (e.g., .2 at sample sizes less than 100, and .1 at sample sizes between 100 and 300) may improve performance at small sample sizes." (Spirtes, Glymour and Scheines, 2000, page 116). Nevertheless, the orientation (edge direction) decision is less reliable than the edge inclusion decision in PC algorithm; results presented below should be viewed with caution and/or interpreted with other relevant information.

Once the price innovations from the ECM estimation are orthoganized, the historical decomposition of the vector *X* at particular time $t=T+k$ can be divided into two parts:

(6) $$X_{T+k} = \sum_{s=k}^{\infty} \Theta_s u_{T+k-s} + \sum_{s=0}^{k-1} \Theta_s u_{T+k-s} .$$

The first term in the right-hand side of equation (6), called the "base projection", utilizes information available up to time period *T*. The second term contains information available from time period $T + 1$ until $T + k$, including the disease outbreaks. The difference between the actual price $\left(X_{T+k}\right)$ and the base price projection $\left(\sum_{s=k}^{\infty} \Theta_s \varepsilon_{T+k-s}\right)$ is thus written as a linear function of innovations (new information) arising in the series between the period *T* and period $T + k$ $\left(\sum_{s=0}^{k-1} \Theta_s \varepsilon_{T+k-s}\right)$. Through the partition, historical decomposition allows to study the behavior of each price series in the neighborhood of important historical events (disease outbreaks in our cases) and to infer how much each innovation contributes to the unexpected variation of X_{T+k} .

Results and Discussion

This paper analyzed weekly observations on prices, imports and shipments of US cantaloupes, spinach and tomatoes around the neighborhood of the disease outbreaks. The data plots are offered to give the readers a sense of the seasonal pattern and consumer response in a neighborhood around each food illness outbreak event. Vertical lines are placed at dates of the outbreaks for each product (Figures 1, 2, and 3). A VAR was fit with 1 lag of levels data, a constant and three quarterly seasonal dummy variables where Schwarz loss was used to select lag length.

Causal pattern on innovations from a vector autoregressions model fit to weekly observation on shipments (S), Imports (I), and Prices (P) for cantaloupes, spinach, and tomatoes are shown in Figure 4 from each separate VAR. Cantaloupe innovations are connected with information flows among domestic shipments, imports and prices, but it is not certain which variables causes which. Spinach innovations are contemporaneously independent. And contemporaneous innovations in tomatoes are modeled as in inverted fork, with imports innovations being caused by innovations in prices and domestic shipments. In contemporaneous time tomato prices and domestic shipments appear to be unrelated. Based on the contemporaneous structures in Figure 4 and the estimated VARs for each series historical decomposition of each price series is obtained.

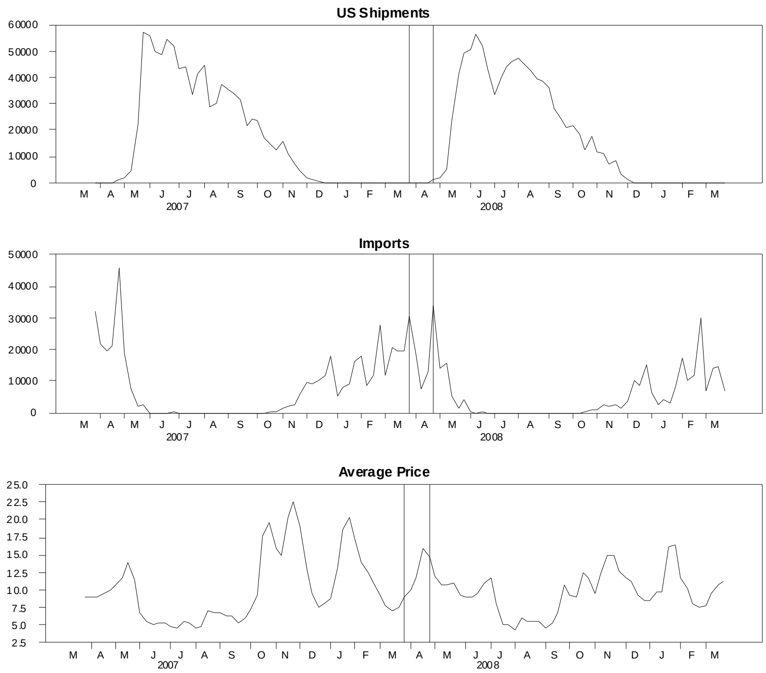


Figure 1. Time Series Plots of Shipments, Imports, Prices of Cantaloupes - Weekly Data, March 31, 2007 – March 28, 2009.

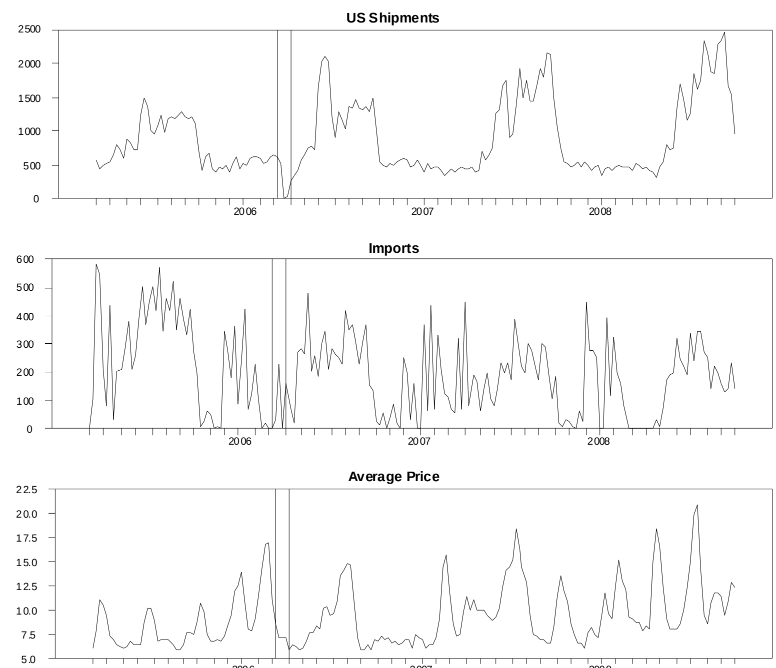


Figure 2. Time Series Plots of Shipments, Imports, Prices of Spinach - Weekly Data, September 3, 2005 – April 4, 2009.

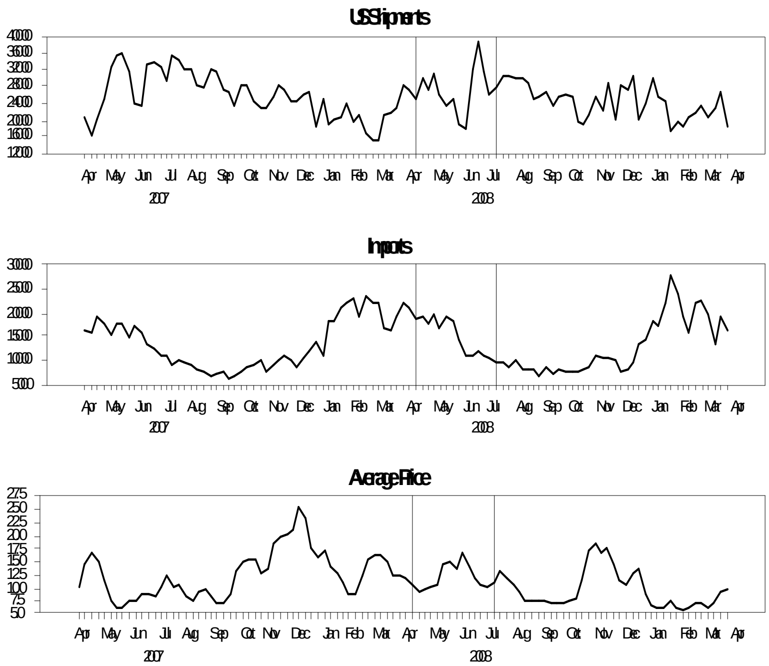


Figure 3. Time Series Plots of Shipments, Imports, Prices of Tomatoes - Weekly Data, April 14, 2007 – April 4, 2009.

Historical decomposition of each price series following equation (6) are offered in Tables 1, 2 and 3. The decomposition analysis starts the week of the original warning of the food outbreak and run it for several weeks after the event to observe how information arising in each series, price, shipments and imports affected price at each weekly observation. In Table 1 cantaloupe price is decomposed before and after the food outbreak. After an initial slightly lower price than forecasted, actual price seems to be above forecasted price in the weeks following the outbreak as evidence by mostly positive numbers (column 5). Most of the cantaloupes sold at the time of the outbreak were imported, since the domestic production season was just about to begin (USDA, 2007). After the initial FDA warning of an outbreak with a foreign source and the following restrictions on imports, prices increased above those levels forecasted prior to the food outbreak. Information arising from prices and imports dominates other new price information. The depth of this cantaloupe outbreak event was the week of April 19, 2008 with the dominate pressure for the +$4.70 price difference increase being accounted from the price innovation itself (+$4.19). The following week shows a reduction in actual prices with domestic shipment information having a larger impact on price information which may be due to more domestic product coming into the market at that time.

Table 2 summarizes a similar price, shipment and import innovation responses following the September 2006 food event in spinach. Here there is an overall negative response in price following the event. Actual prices were below forecasted prices with the knowledge prior to the food outbreak. Most of this negative information arises in the price market itself, suggesting that a drop in consumer demand may be behind the fall off in prices. Innovations in shipments actually show very little negative influence on price.

Interestingly, since the food outbreak was associated with a domestic source, import information shows a positive, but small effect on price information. The highest intensity of the spinach event was the week of September 9, 2006 with the dominate pressure for the -$4.29 price difference drop being accounted almost totally from the price innovation (-$4.33)

Table 1. Historical Decomposition of Cantaloupe Price in a Neighborhood of the March 22, 2008 and April 26, 2008 Event.

(1) Date	**(2) Difference = Actual Price Minus Forecasted Price**	**(3) Due to Information Arising from Domestic Shipments**	**(4) Due to Information Arising from Imports**	**(5) Due to Information Arising from Price**
March 22, 2008	-0.02	0.00	0.00	-0.02
March 29, 2008	0.19	-0.16	-0.49	0.84
April 5, 2008	-0.72	-0.33	-2.21	1.82
April 12, 2008	0.59	-0.14	-1.54	2.28
April 19, 2008	4.70	0.34	0.17	4.19
April 26, 2008	3.51	1.06	0.45	2.00

Note: This table decomposes the difference between the Actual Price and the Forecasted Price at each date, between March 29, 2008 and April 26, 2008. That difference at each date can be attributed to information arising in the domestic shipments variable, the imports variable and the price variable. Accordingly, the column labeled (2) is decomposed at each date into the sum of columns (3), (4) and (5).

Table 2. Historical Decomposition of Spinach Price in a Neighborhood of the September 9, 2006 and October 4, 2006 Event.

(1) Date	**(2) Difference = Actual Price Minus Forecasted Price**	**(3) Due to Information Arising from Domestic Shipments**	**(4) Due to Information Arising from Imports**	**(5) Due to Information Arising from Price**
September 2, 2006	-4.12	0.00	0.00	-4.12
September 9, 2006	-4.29	-0.00	0.04	-4.33
September 16, 2006	-3.81	0.00	0.09	-3.88
September 23, 2006	-3.87	0.01	0.13	-4.02
September 30, 2006	-3.42	0.02	0.00	-3.44
October 7, 2006	-3.20	-0.26	0.01	-2.96
October 14, 2006	-2.49	-0.60	0.07	-1.96

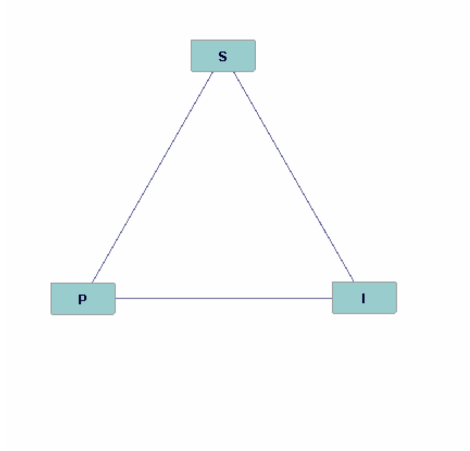
Note: This table decomposes the difference between the Actual Price and the Forecasted Price at each date, between September 2, 2006 and October 14, 2006. That difference at each date can be attributed to information arising in the domestic shipments variable, the imports variable and the price variable. Accordingly, the column labeled (2) is decomposed at each date into the sum of columns (3), (4) and (5).

Table 3 offers price decompositions for tomatoes just before and following the outbreak event in tomatoes that found a foreign source in peppers. The results are similar to the cantaloupe event, with actual prices being higher than forecasted prices most of the time. In tomatoes however, the new information arising comes from information in all domestic shipments, imports and prices. The highest intensity of the tomato outbreak was on the week of June 14, 2008, a week after the original FDA warning of a potential illness outbreak in tomatoes, with the dominate pressure for the +$6.41 price difference increase being accounted by domestic shipments, imports and prices; the latter having the greatest price impact with +$4.25.

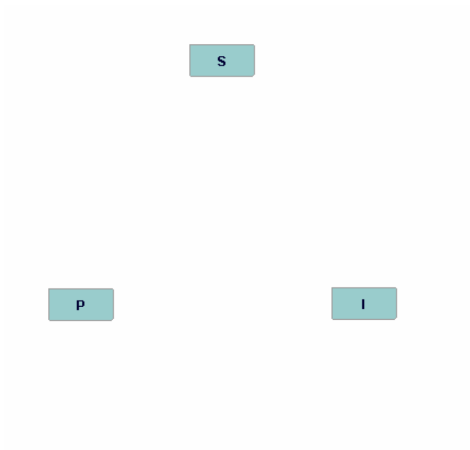
Table 3. Historical Decomposition of Tomato Price in a Neighborhood of the April 12, 2008 and July 19, 2008 Event.

(1) Date	(2) Difference = Actual Price Minus Forecasted Price	(3) Due to Information Arising from Domestic Shipments	(4) Due to Information Arising from Imports	(5) Due to Information Arising from Price
April 12, 2008	1.76	-0.15	-0.91	2.82
April 19, 2008	0.26	-0.28	-0.74	1.27
April 26, 2008	-0.91	-0.12	0.03	-0.82
May 3, 2008	-0.09	-0.24	0.20	-0.05
May 10, 2008	0.35	-0.23	0.60	-0.02
May 17, 2008	0.78	-0.41	0.42	0.77
May 24, 2008	4.34	-0.28	0.94	3.68
May 31, 2008	5.06	0.28	0.44	4.34
June 7, 2008	3.44	0.58	0.32	2.54
June 14, 2008	6.41	1.22	0.94	4.25
June 21, 2008	4.06	2.19	1.20	0.67
June 28, 2008	1.99	1.75	0.76	-0.52
July 5, 2008	0.72	0.27	0.43	0.02
July 12, 2008	-0.01	-0.66	0.00	0.65
July 19,2008	0.34	-0.59	-0.56	1.50

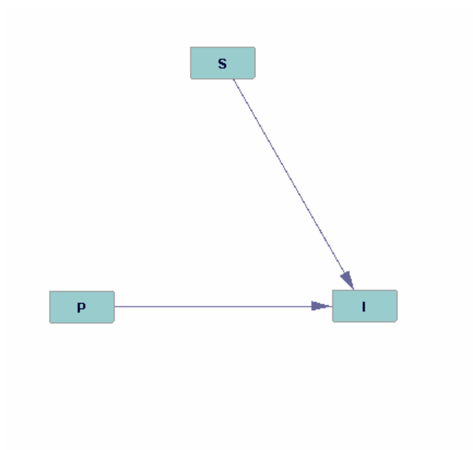
Note: This table decomposes the difference between the Actual Price and the Forecasted Price at each date, between April 12, 2008 and July 19, 2008. That difference at each date can be attributed to information arising in the domestic shipments variable, the imports variable and the price variable. Accordingly, the column labeled (2) is decomposed at each date into the sum of columns (3), (4) and (5).



Cantaloupes



Spinach



Tomatoes

Figure 4. Causal Pattern on Innovations from a Vector Autoregressions Models Fit to Monthly Observations on Shipments (S), Imports (I), and Prices (P) for Cantaloupes, Spinach and Tomatoes.

Several studies have looked at the economic and consumer effects of a food outbreak, including Worth (2000), Buzby (2001), Calvin et al. (2004), and Onyango (2007). When calculating the associated costs of a food safety outbreak to a particular industry, most of the literature focuses on the retail level. This paper estimated the short-run farm level cost of the cantaloupe, spinach and tomato outbreaks to its respective industries at the farm level. In order to estimate the short-term impacts of these food outbreaks to their industry, domestic shipments, imports and prices were forecasted using only information known prior to the food outbreaks. The difference between forecasted variables and actual values is attributed to information arising from the outbreaks. The forecasting technique used to estimate domestic shipments, imports and prices was a triple exponential smoothing. Triple exponential smoothing is a very popular scheme to produce a smoothed time series and accounts trend and seasonality, as well as overall smoothing of the data (Hyndman et al., 2008). In this study, it was estimated that the short-term farm level losses for US spinach were over $8 million. Actual domestic shipments of spinach dropped 7,088 metric tons from the forecasted level prior to the spinach outbreak while actual imports were 3,531 metric tons above the forecasted level. US tomato farm losses were estimated at $25 million. Tomato imports levels were 96,900 metric tons or $97 million above the forecasted level, as imports from Canada offset the decrease in imports from Mexico. Finally, short-term farm level cantaloupe losses were estimated at $5.8 million for the domestic market, and $29.5 million for imports, as the contamination source was found to be foreign. Domestic shipments of cantaloupe were 9,843 metric tons below the forecasted levels prior to the cantaloupe incident, while actual imports decreased 36,508 metric tons from the forecasted level.

Summary and Conclusions

Historically the United States was perceived to have the safest food supply in the world. While, in fact, this may still be true, a number of incidents have led to questions regarding the safety of the U.S. food supply. Three case studies were analyzed to assess the potential impacts of food safety outbreaks on domestic shipments, imports and prices of the produce industry: the cantaloupe outbreak of March-April 2008, the spinach outbreak of September 2006, and the tomato outbreak of June-July 2008.

Data determined historical decompositions were conducted to provide a weekly picture of domestic shipment, import and price fluctuation transmissions. The empirical analysis based on a vector autoregression (VAR) model showed differences in the results depending on the source of the outbreak (domestic versus imported). Cantaloupe innovations are connected with information flows among domestic shipments, imports and prices, but it is not certain which variables causes which. Spinach innovations are contemporaneously independent. And contemporaneous innovations in tomatoes are modeled as in inverted fork, with imports innovations being caused by innovations in prices and domestic shipments. Historical decomposition of each price series showed similar results for cantaloupes and tomatoes (both had original warnings linked to a potential foreign source) with actual prices being higher than forecasted prices with information arising prior to the outbreaks. In spinach there was an overall negative response in price, with actual prices below forecasted prices. Most of this negative information on spinach arises in the price information itself, suggesting that a drop in consumer demand might be behind the fall in spinach prices.

The short-term farm level impacts of the cantaloupe, spinach, and tomato food outbreaks to their industry was estimated by forecasting domestic shipments, imports and prices using only information known prior to the food outbreaks. The difference between forecasted variables and actual values is attributed to information arising from the outbreaks. It was estimated that the short-term farm level losses for US spinach were over $8 million. Domestic shipments of spinach dropped 7,088 metric tons. US tomato farm losses were estimated at $25 million. Finally, short-term farm level cantaloupe losses were estimated at $5.8 million for the domestic market, and $29.5 million for imports, as the contamination source was found to be foreign.

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