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Price Transmission and Food Scares in the U.S. Beef Sector

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Price Transmission and Food Scares in the U.S. Beef Sector

Grigorios Livanis (*University of Florida*) and Charles B. Moss (*University of Florida*)

***Abstract*:** The advent of mad cow disease in Canada in the United States raises numerous concerns regarding consumer reaction to information in the United States. To examine the role of consumer reaction to information we examine the response of price spreads in the U.S. beef market to a Food Safety Index derived from Lexis-Nexis. Specifically, we estimate a vector error correction model to examine the long and short-run effect of news on price spreads. Our results indicate that informational shocks are fairly transient in the retail prices, but persist at the wholesale and farm level.

***Keywords*:** vector error correction, food safety, price spread, beef markets

The incidence of foodborne diseases has dramatically increased in the past fifteen years in the United States and in other industrialized countries, partially as a result of better surveillance programs or by the appearance of new pathogens. According to the Centers for Disease Control and Prevention (CDC) the incidence of food borne disease outbreaks in the United States was in the range of 500-800 for the period 1990-1997, while in the period 1998-2001 (CDC initiated improved reporting in 1998) increased to 1026-1380. Parallel to this increase, widely publicized outbreaks have led to greater consumer awareness about potential food hazards and demand for safer products. Even more it has led, in some cases, to disruption of international trade for food and agricultural products.

The impact of food safety information and in particular food scares, as well as product recall information, on consumer demand for food and agricultural markets has been extensively

analyzed in the literature. These studies can be categorized into three general approaches. The first set of studies use direct elicitation of consumer preferences methods such as contingent valuation, conjoint analysis and experimental auction to value food safety information and recover stated and/or revealed preferences of the consumer for food safety. For instance, Dickinson and Bailey (2002) found that consumers in the state of Utah are willing to pay the cost for a greater transparency in red-meat products. Another set of studies focuses on consumer response to food borne disease outbreaks providing various explanations for either short-run or long-run consumer behavior. Most notably, Jin and Koo (2003) and Peterson and Chen (2003) in their analysis for Japanese consumers and Mangen and Burrell (2001) for Dutch consumers have found that consumers' tastes for meat have systematically moved away from beef to its substitutes following the discovery of BSE. Finally the third set of studies focuses on the impact of food safety information on the demand for the risky good. Food safety information is captured through an index based on media articles or television publicity of food borne disease outbreaks. For instance, Piggott and March (2004) analyzed the impact of food safety information on US meat demand and found that the average demand response to food safety concerns was small for the period 1976-1999. Finally, Huang et al. (2004) after eliciting through surveys consumers' perceived risks, they estimated the impact of those risks to seafood consumption in North Carolina.

Another extensive strand of literature has examined price linkages among farm, wholesale, and retail markets for meat and livestock products in several countries (Palaskas 1995, von Cramon-Taubadel 1998, Goodwin and Holt 1999, Tiffin and Dawson 2000, Abdulai 2002). The general result of these studies is that the transmission between farm, wholesale and retail prices is asymmetric, whereas there is a unidirectional price transmission from producers to

retailers. Further, a number of these studies could not find a long-run relationship for meat prices, especially for the United Kingdom.

Although these studies provide many significant results and insights, there has been little analysis of the impact of food scares on prices at different stages of the beef marketing chain in the United States. Such an analysis becomes essential if we notice that, in spite of increased consumer awareness to food safety, real prices in the retail U.S. beef sector have fallen by only 5% (on average) during the period 1990-2004, while in the wholesale and farm sector have decreased by 38% and 37% respectively. In support of this result, during this period all price spreads have been observed to grow, but the retail-wholesale price spread has grown five times more than the wholesale-producer spread (on average). A possible explanation of this outcome can be attributed to an increased industry concentration and exertion of market power, given the mergers and acquisitions in the meatpacking industry. Further, the U.S. livestock sector has experienced several structural changes, which apart from the industry concentration are also due to changes in marketing practices, increase in the scale of operations, and regulatory policies, such as the implementation of HACCP from 1997.

Therefore, this study will examine the impact of food scares on U.S. beef prices at different stages of the marketing chain for the period 1990-2004. Goodwin and Holt (1999) examined price transmission of shocks in the producer, wholesale and retail marketing channels in U.S. beef market using a threshold error correction model, and evaluated the dynamic time paths of price adjustments to shocks at each level in the U.S. beef marketing channel. However, their approach does not take into account exogenous demand shocks, such as the increased awareness of consumers in food safety.

Econometric Methods

The methodological approach that this study uses is similar to the study by Lloyd et al. (2001) who showed that food scares in the United Kingdom resulted in decline of prices at each marketing stage. Moreover, these price declines were not equal between stages suggesting that the UK food chain is characterized by some degree of market power. The formal analysis of the present study is conducted in a cointegration framework, where beef prices at each level of the marketing chain are endogenous. To capture the increased awareness of consumers to food safety, we follow Piggott and Marsh (2004) by constructing a food safety index based on newspaper articles from the popular press in the period 1990-2004. Since the food safety index is an exogenous shock to beef demand, we assume that changes in this index cause price changes and not the reverse. Tests include unit root of each time series and a system cointegration test where we test for unknown structural breaks in each series, using recently developed techniques in the literature. The latter constitutes the departure from the Lloyd et al. study and a significant addition to the literature. We follow the studies by Lutkepohl et al. (2004) to test for unknown structural breaks in the cointegrating relationship; and Saikkonen and Lutkepohl (2002) for the unit roots. Further, we derive the impulse response functions of the three prices to a unit shock of the food safety index.

To investigate the order of integration I(.) of the four individual series we use the Augmented Dickey Fuller (ADF) test. However, if there is a level shift in the level of the data generating process (DGP), then the ADF test may be distorted. Thus, we use the tests of Saikkonen and Lutkepohl (2002), Lanne, Lutkepohl and Saikkonen (2002, 2003) to first search for a structural break in each individual series and then test for a unit root. To illustrate this test

we consider a special case of Saikkonen and Lutkepohl (2002). Thus, let an individual time series x_t, ($t = 1,...,T$) be generated by the following mechanism

$$x_t = \mu_0 + \mu_1 t + \delta d_t + z_t \tag{1}$$

where d_t is a simple shift dummy $\{d_t = 0$ if $t < T_B$ and $d_t = 1$ if $t \geq T_B\}$, (μ_0, μ_1) are deterministic terms and z_t is an unobservable stochastic error generated by an AR(p) process with possible unit root. To test for a unit root Saikkonen and Lutkepohl (2002) propose to estimate the deterministic part first by a generalized least squares procedure and then subtract it from the original series. Then an ADF test can be performed on the adjusted series $\hat{z}_t = x_t - \hat{\mu}_0 - \hat{\mu}_1 t - \hat{\delta} d_t$. Critical values are reported in Lanne, Lutkepohl and Saikkonen (2002).

The cointegration analysis applied in this study follows the approach developed by Johansen (1988) and Johansen and Juselius (1990). Following a more extensive discussion of the model presented in Johansen (1995), the estimation procedure is based on the error correction formulation

$$\Delta x_t = \Pi x_{t-1} + \Gamma_1 \Delta x_{t-1} + \cdots + \Gamma_{p-1} \Delta x_{t-p+1} + \Psi D_t + \nu_t \tag{2}$$

where x_t is the vector of jointly determined I(1) endogenous variables, Δx_t is the difference in x_t, D_t is a vector of deterministic and/or exogenous variables, $\Gamma_1, \cdots \Gamma_{k-1}$, Π, and Ψ are estimated parameters, and ν_t is a vector of n.i.d. disturbances with zero mean and non-diagonal covariance matrix Σ. In this study, the endogenous variables are the natural logarithm of beef prices at various levels of the market channel and the food safety index, whereas the deterministic variables are impulse dummies and a constant term. The endogenous variables are cointegrated if the Π matrix is singular ($\Pi = \alpha' \beta$). The number of cointegrating vectors is determined by the significance of the eigenvalues of Π or by the trace statistic. Cheung and Lai

(1993) suggest that the trace test shows more robustness to both skewness and excess kyrtosis in the disturbances than the maximum eigenvalue. Following this result the choice of the rank r will be based on the trace statistic. Within this formulation the β matrix contains the long-run equilibria, while the α matrix depicts the speed of adjustment toward the long-run equilibria.

To investigate the impact of changes in the food safety index, in the marketing chain prices we will perform impulse response analysis. Thus, consider the level representation of (2), which is a vector autoregressive process VAR(p):

$$x_t = \Phi_1 x_{t-1} + \Phi_2 x_{t-2} + \cdots + \Phi_p x_{t-p} + \Psi D_t + \nu_t \tag{3}$$

Lutkepohl and Reimers (1992) showed that the impulse response function can be found by imposing a recursive structure on the moving average representation of the VAR (equation 3) $\Phi_s = (\varphi_{ij,s}) = \sum_{k=1}^{s} \Phi_{s-k} A_k$, where $\Phi_0 = \mathrm{I}_n$, $A_k = 0$ for $k > p$. The impulse response function of variable i with respect to a unit shock to variable j, s periods ago, everything else constant is given by a plot of $\varphi_{ij,s}$. In this analysis we report orthogonal impulse responses but notice that the results depend on the order in which the variables appear in the VAR.

Data and Results

Our empirical model analyzes three series of monthly beef prices and one series of a food safety index from January 1990 to December 2004, giving a total of 180 observations. All price data were obtained from the Economic Research Service of the USDA. The food safety index is constructed based on newspaper articles from the popular press. Data for this index were obtained by searching the top fifty English language newspapers using the academic version of the Lexis-Nexis search tool. Keywords searched were *food safety* or *food contamination* or *beef*

outbreak. Then the search was narrowed only to information about beef by using the additional term *beef*.

Figure 1 presents the monthly food safety index. Some information on the outbreaks and regulatory policies follows. In December 1995 there was the first suspicion about potential link of BSE to CJD, which was confirmed in March of 1996. In July of 1996 USDA announced the Pathogen reduction and Hazard Analysis and Critical Control Points (HACCP) regulation. According to this rule all establishments would be required to enforce sanitation standard operating procedures by January 27 of 1997, as well as *E. coli* process control testing. The HACCP regulations and provisions of the rule were applicable to large establishments (500 or more employees) in January 26, 1998 and gradually until 2000 for the smaller establishments. In August of 1997, the largest meat recall in U.S. history as Hudson Foods Company linked to the outbreak of *E. coli*-tainted hamburgers and agreed to put off the market and destroy 25 million pounds of ground beef. In June 1999 U.S. banned beef imports from Europe, while dioxins were found in milk in Germany. In December, 2000 Europe bans beef over 30 months from the U.K. while in U.S. there was another meat recall due to *E. coli* (1 million pounds of ground beef). In July 2002 ConAgra in U.S. recalled 354,200 pounds of ground beef and 19 million pounds of beef trim and frozen, fresh ground beef due to contamination by *E. coli*. Finally, in March 2003 Canada had its first case of BSE, while U.S. had its first case in December of 2003 from a cow that came from Canada.

Figure 2 shows monthly net farm, wholesale, and retail values for beef, where they have been corrected for inflation by the consumer price index (CPI). The general trend after correcting for inflation is downward until the end of 1996, while from January of 1997 there is an upward trend in the series and especially in the net farm and wholesale prices. Therefore, the prices that

consumers pay for beef have increased less rapidly than inflation until the end of 1996. In other words, the real cost of beef was declining. However, from January 1997, which coincides with the enforcement of the sanitation standard operating procedures in all establishments in U.S., it is observed that all prices were increasing; most probably caused by the implementation cost of the regulation.

Transforming all price series and the food safety index in natural logarithm form, we test each series individually for a possible structural break using the method of Saikkonen and Lutkepohl (2002), after correcting for autocorrelation. We found no statistical significant structural break for the retail price series and so we performed an ADF test for unit root[1]. Table 1 indicates that retail price is integrated of order one I(1), where two lags orders were included according to the Akaike information criterion (AIC) and Hannan-Quinn (HQ) criterion, as well two deterministic terms: a constant and a trend. Once the series is differenced then the ADF test with a constant but no trend indicates that the series is stationary. As Table 2 indicates, there was a structural break in each of the other series. Specifically, the natural logarithm of the food safety index, has an impulse dummy break at 1996: M3 (dummy is 1 in this month and zero otherwise) as it was expected from visual observation of Figure 1. To test for the order of integration we used the Saikkonen and Lutkepohl (2002) test, which clearly shows that the safety index has a unit root for a lag order of three. The producer and wholesale prices both had a structural break at 1996: M11, which is before the start of the sanitation standards regulation. The break in both prices is captured with a shift dummy that is one after the break and zero otherwise. An analysis of the first differences of the two variables rejects unit roots in these series. Taking into consideration the results on the levels of those two variables it is evident that the variables are

[1] Most of the analysis was performed in the JMulTi program developed by Lutkepohl and Kratzig, and is available online at www.jmulti.com.

well modeled as I(1). The first differences of the variables do not have a level shift anymore but just an outlier in November of 1996, which is captured by using an impulse dummy variable in these tests.

The next step of the analysis is to investigate the number of cointegrating relations between the series. Assuming a constant and a trend in the cointegrating relationships, and using the Johansen's Trace Statistic in Table 3 and the published statistics in Case II Table B.10 in Hamilton, we conclude that there are three cointegrating vectors. To check the robustness of this result we allowed for a shift dummy in 1996:M11 and an impulse dummy in 1996:M3, along with a constant and a trend. To test for the cointegrating rank in this case, we used the test of Saikkonen and Lutkepohl (2000), which is presented in Table 4. We conclude that the data exhibits three cointegrating relationships. Thus, as in Lloyd et al. (2001) for the U.K. the food safety index is plays an important role in the long-run relationship of beef prices in the United States.

Using the previous results, we consider a VECM (equation 2) for the four-dimensional series with cointegrating rank three and two lagged differences. Moreover, the shift dummy is included in differenced form and so it becomes an impulse dummy. Thus, the deterministic terms in the VECM are the impulse dummies for 1996 (M3 and M11) and a constant term. A linear trend term was added initially but it was found to be insignificant. The resulting maximum likelihood estimator of the cointegrating vector is presented in Table 5.

The orthogonalized impulse response functions of the three beef prices to a one percent shock in the food safety index are presented in Figure 3. It is evident that the producer and the wholesale price immediately fall by the same amount from increased consumer awareness about food safety, as captured by the index. Instead, the retail prices initially increase for a short period

of time but then fall. The recovery of each series to its pre-shock level is faster for the retail prices with the producer prices taking the most time. In the long-run though, all prices increase as is evident also from Figure 2.

These results indicate that the food safety index is important in determining the long-run relationship of the beef prices. Increased food-safety concerns lead to a drop in the prices at all stages in the marketing chain but the recovery period from the shock differs across stages. It is evident that retail prices are the least affected from increased food scares in the short-run, while producer and wholesale prices suffer the most. The importance of food safety regulations such as the HACCP is also evident in Figure 2, since if the food safety concern was repeated and consumers were not assured about the quality of the product then a shock in the food safety index could have caused a decrease in all prices in the long-run.

Summary and Conclusions

This paper analyzed the effect of food-safety concerns on beef prices at the producer, wholesale and retail level. We find that these concerns affect the long-run equilibrium of the beef prices at each stage of the supply chain. In particular, we captured the awareness of the consumers towards food safety by constructing an index based on popular press articles on food contamination concentrating on beef. We show that this index was cointegrated with beef prices and the long-run relationship was found using a VECM. Moreover, we show that a shock in the system caused by one percent change in the food safety index has different effects on each price series. Specifically, retail prices were the less respondent to this shock, while producer prices had the longer recovery period. The importance of food safety regulations such as the HACCP was also demonstrated by the fact that all prices in the long-run were increasing after an exogenous shock in the demand. This may have also implications about the mandatory country-of-origin

labeling for beef products that is effective in 2006. If country of origin labeling increases consumers' awareness about the safety of the domestic products, its implementation cost will be absorbed by the consumer in the long-run. This pattern was observed for the introduction of HACCP, where we observed real prices at all stages of the marketing chain to increase from 1997 and onwards.

Finally, the mad cow case in the United States could not be sufficiently captured by the dataset, for instance as a potential structural break in the cointegrating relationship, because of the short period of data available after its incidence.

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Figure 1. Food Safety Index

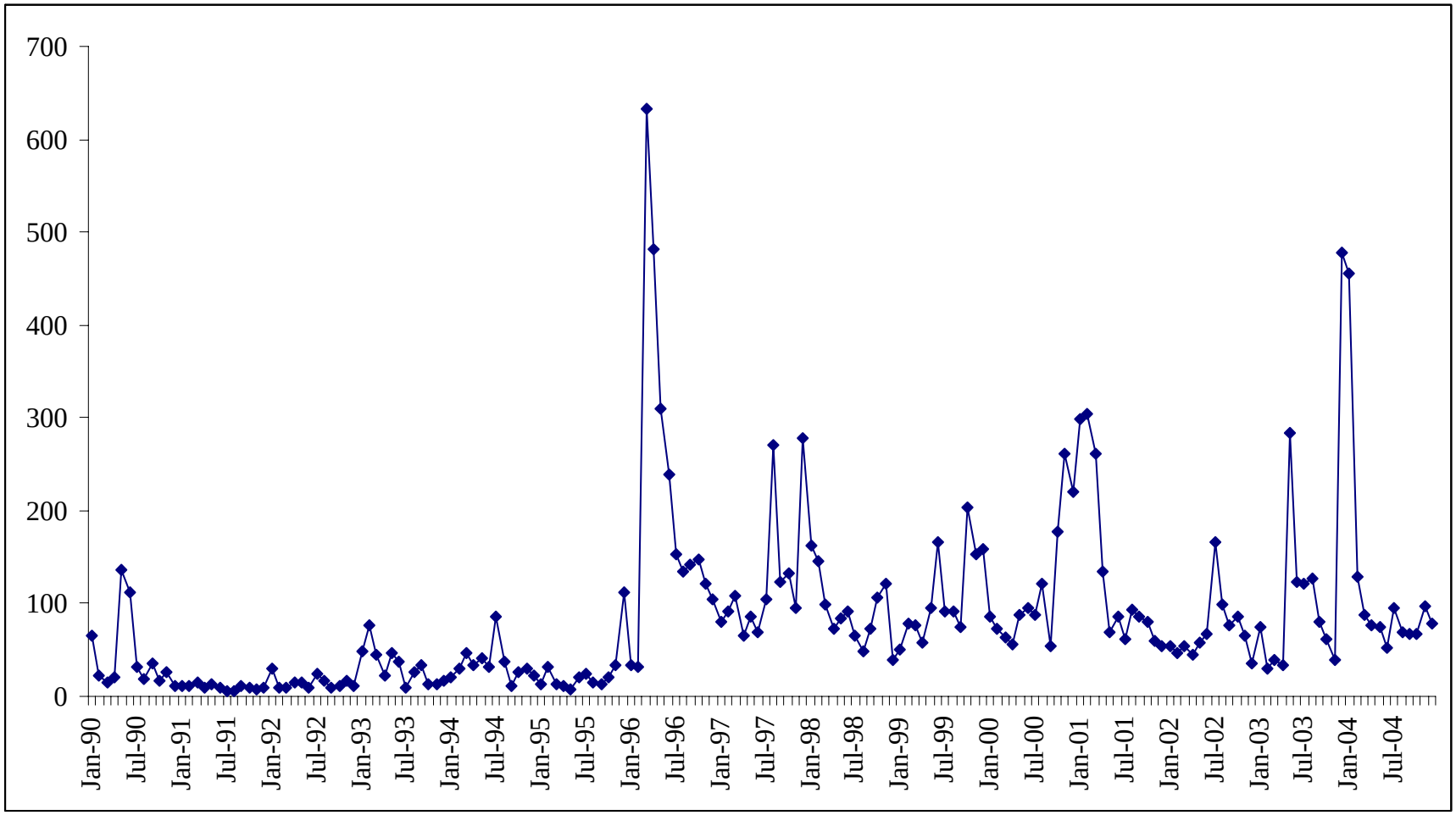

Figure 2. Real Monthly Beef Prices

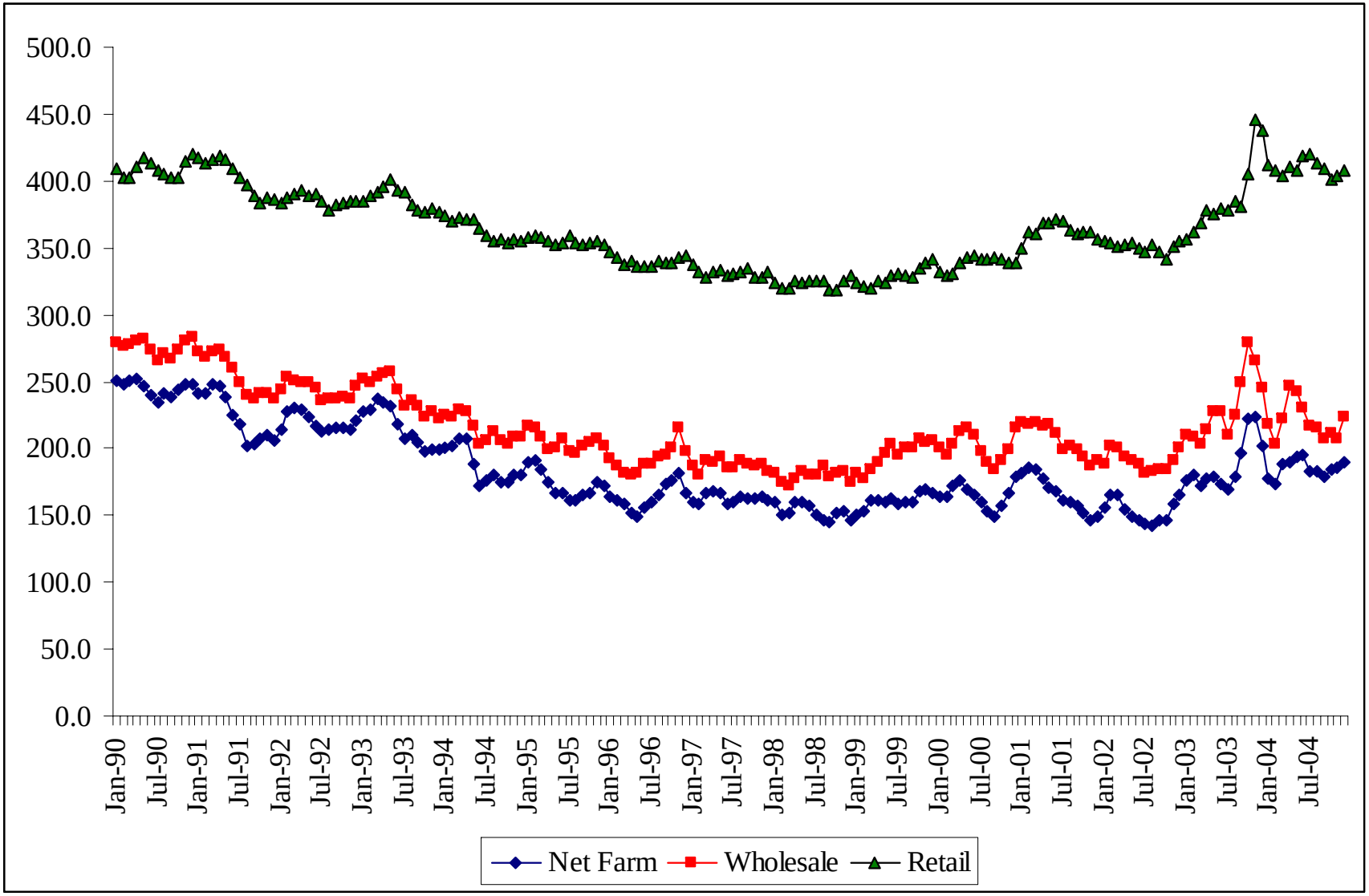

Figure 3. The Dynamic Effect of Shocks to the Food Safety Index

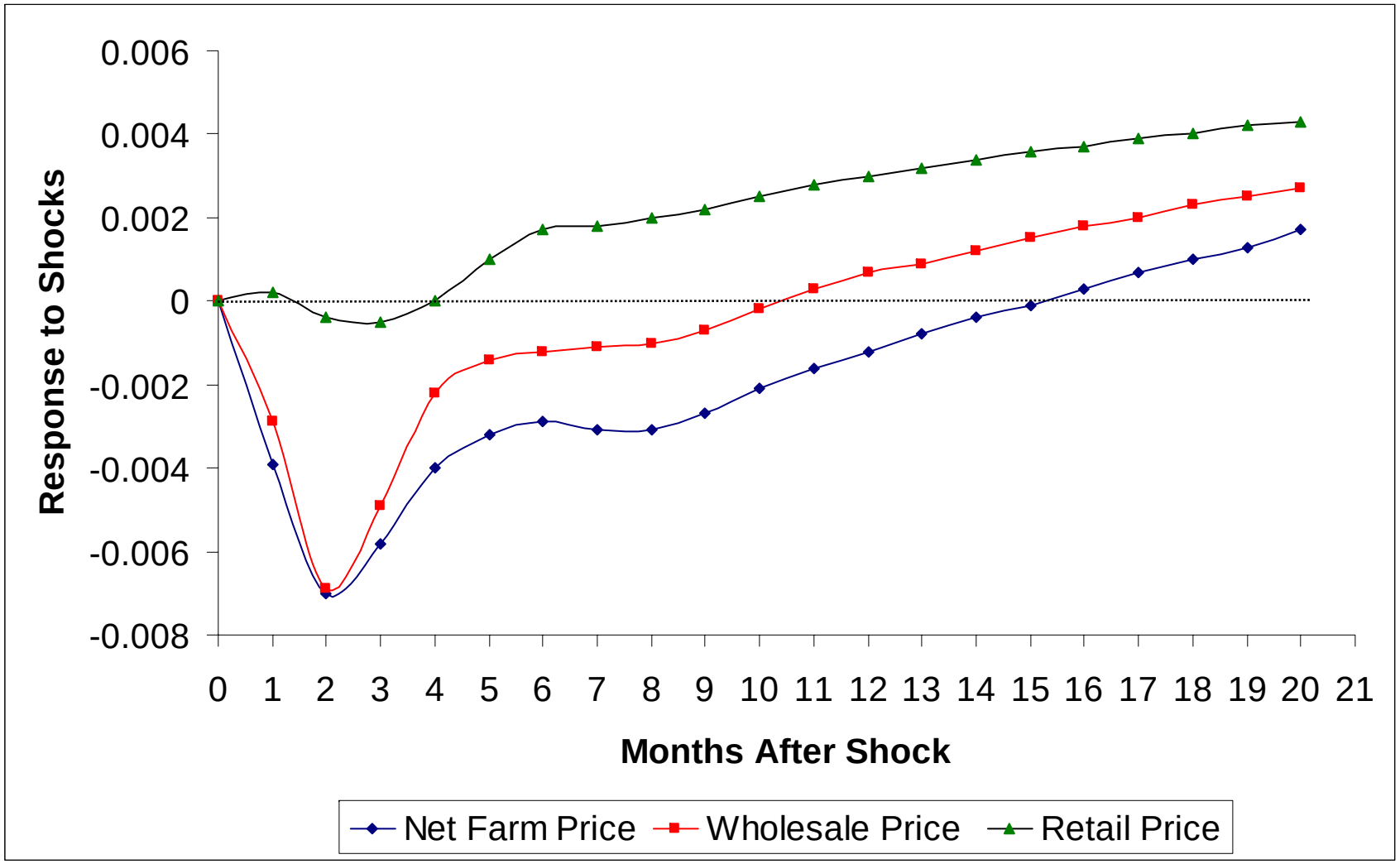

Table 1. ADF Tests for Retail Price

Variable	Levels (lag)	5% critical value	Differences (lag)	5% critical value
retail price	-0.6658(2)	-3.41	-10.52 (1)	-2.86

Notes: Lag length for the ADF regression selected according to the Akaike Information Criterion (AIC) and Hannan-Quinn Criterion and are reported in parentheses adjacent to the test statistics. The levels regression includes a constant and trend and the differences includes only a constant.
Critical values from Davidson and MacKinnon (1993).

Table 2. Unit Root Tests in the Presence of Structural Shifts for Net farm, Wholesale Prices and Food Safety Index

Variable	Break Date	Shift function	Levels (lag)	5% critical value	Differences (lag)	5% critical value
farmp	1996: M11	Shift dummy	-1.95 (3)	-3.03	-9.40 (2)	-2.88
wholesp	1996: M11	Shift dummy	-1.78 (3)	-3.03	-10.61 (2)	-2.88
FSI	1996: M3	Impulse dummy	-2.64 (3)	-3.03	-11.96 (2)	-2.88

Notes: Lag length for the unit root regression selected according to the Akaike Information Criterion (AIC) and Hannan-Quinn Criterion and are reported in parentheses adjacent to the test statistics. The levels regression includes a constant and trend and the differences includes only a constant. Notice that in differences the shift dummies become impulse dummies.
Critical values from Lanne, Saikkonen and Lutkepohl (2002).

Table 3. Cointegration Test Statistics

H_0	LR Trace Statistic	5% Critical Values
$r = 0$	115.05	63.66
$r = 1$	67.29	42.77
$r = 2$	30.96	25.73
$r = 3$	4.06	12.45

Note: This test is based on Johansen's procedure (1991).

Table 4. Cointegration Test Statistics with Shift and Impulse Dummies

H_0	LR Trace Statistic	5% Critical Values
$r = 0$	115.05	63.66
$r = 1$	67.29	42.77
$r = 2$	30.96	25.73
$r = 3$	4.06	12.45

Note: This test is based on Saikkonen and Lutkepohl (2000).

Table 5. Cointegrating Vector

Endogenous Variable	Vector 1	Vector 2	Vector 3
Farm Price	1.000	0.000	0.000
	(0.000)[a]	(0.000)	(0.000)
Wholesale Price	0.000	1.000	0.000
	(0.000)	(0.000)	(0.000)
Retail Price	0.000	0.000	1.000
	(0.000)	(0.000)	(0.000)
Food Safety Index	0.354	0.332	0.313
	(0.062)	(0.062)	(0.072)
Constant	-6.597	-6.677	-7.145
	(0.253)	(0.250)	(0.291)

[a]Numbers in parenthesis denote standard deviations