HOW SCARY ARE FOOD SCARES? EVIDENCE FROM ANIMAL DISEASE OUTBREAKS

by

DWIGHT MATTHEW HOUSER

(Under the Direction of Berna Karali)

ABSTRACT

Abnormal volatility levels have persisted for an extended period in livestock markets. Some of the most significant shocks have come from animal disease outbreaks, such as Bovine Spongiform Encephalopathy (BSE) and the H1N1 flu. Although there has been considerable research to examine the impact of disease outbreaks on cattle markets, these studies have not extensively investigated the volatility component of financial data. Since it has been shown that futures prices exhibit time-varying variance, investigating volatility of livestock futures prices in response to BSE and H1N1 will reveal the resilience of commodity markets during large food scare outbreaks. Using a regression framework to measure abnormal returns and variances as regression coefficients, we find that livestock futures markets are affected during animal disease outbreaks with returns decreasing and the variance increasing, on average, during these events. In certain cases, outbreaks impact the volatility of a substitute commodity.

INDEX WORDS: BSE, Futures Market, Food Scare, H1N1Volatility,

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DWIGHT MATTHEW HOUSER

B.A., Georgia College, 2012

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2017

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DWIGHT MATTHEW HOUSER

Major Professor:	Berna Karali
Committee:	Travis A Smith
	Chen Zhen

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
August 2017

DEDICATION

To my parents, mentor and wife. Thank you for all your love and support.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my advisor Dr. Karali for the continuous support of my Master’s study, for her patience, motivation, and immense knowledge.

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CHAPTER 1

INTRODUCTION

Recently, livestock commodities have displayed considerable volatility in financial markets, making it more difficult for producers to use futures markets to hedge against price risks. Over the past twenty years, macroeconomic, political, weather and foreign trade events have contributed to this market uncertainty. One of the most significant shocks to livestock was the 2003 Bovine Spongiform Encephalopathy (BSE) or 'mad cow' disease. It resulted in a five-month abnormal impact on U.S. live cattle futures prices (Jin et al., 2008). For the first time since November 1987, thirty-day volatility surpassed the 20 percent mark, reaching as high as 23.8 percent in late 2003 (Brix, 2016). Similarly, the 2009 H1N1 flu outbreak in the U.S. resulted in significant and prolonged losses in meat markets – particularly, hogs – due to its nominal association to pork through its label 'swine flu' (Attavanich, 2002). The effects on derivative returns and volatilities following these outbreaks present ongoing economic concerns.

Early literature utilized recall events to analyze the economic impacts of safety events (Pozo and Schroder, 2016), identifying adverse reactions to recalls involving serious food safety hazards (McKenzie and Thomsen, 2001). Food scares may be more pernicious than recalls because there is little time for market adjustment and the economic losses are larger (Henson and Mazzocchi, 2002). Food scares are characterized by a sudden disease outbreak that leads to an unparalleled market reaction and heightened consumer anxiety, stemming from the uncertainty related to illness. There is considerable uncertainty surrounding BSE and H1N1 flu, much due to their infrequent occurrence and fatal consequences. Abnormal returns have been found in financial markets for both diseases; however, the degree of impact on futures markets of both outbreaks on returns and variances, while incorporating spillover effects, has not been addressed in the literature.

Motivation

Food scares result in severe economic losses in areas of consumption, production, trade, and finance. H1N1 yielded a $200 million market revenue loss for the pork industry over a four month span, while the 2003 BSE outbreak in the U.S. significantly reduced beef sales for nearly three months (Attavanich et al., 2011; Schlenker and Villa-Boas, 2008). The unpredictable behavior of livestock markets has made decision-making difficult for market participants. Unanticipated events, such as disease outbreaks, have only increased this volatile behavior, thus increasing risk. There is now a wider range for prices to deviate with food scares creating greater fluctuations in food prices. Unfortunately, BSE and animal flu strains have not been eradicated, thus presenting an ongoing threat to society and the economy. The motivation for this study is to provide information to producers, market analysts, and policymakers concerning impacts of animal disease outbreaks on financial markets, specifically on abnormal returns and variance measures of derivative prices. This information will inform producers about the linkage between livestock markets. Through understanding the relationship among commodities during disease outbreaks, this study will guide policymakers in implementing price stabilization measures in such a crisis. It will also elucidate the behavior of derivatives during food scares in general.

Objectives

To accomplish our task, we measure the impact of animal disease outbreaks on futures market returns and variances. Specifically, this study examines live cattle and lean hog futures prices following three North American BSE cases and one H1N1 flu event. We also evaluate the volatility spillover effects between the two livestock markets. Furthermore, we analyze these measures for different contract maturities to understand the time horizon of the outbreak impacts. Significant effects on deferred contracts, if any, could help explain possible prolonged effects on consumer demand and trade.

The following section presents a literature review related to the impacts of various food safety events on futures market prices. This is followed by an account of the data used. Then, empirical methodology is described followed by empirical results. Conclusions, implications, and further research are discussed in the last section.

CHAPTER 2

LITERATURE REVIEW

The following chapter contains the current knowledge of substantive findings related to food safety economics and empirical methodological contributions used to examine its effects on financial markets.

Food Safety Literature

The early food safety literature examined non-price factors, including health concerns, to analyze economic trends in consumer demand and commodity prices. Moschini and Meilke (1989) found that dietary concerns provided the best explanation for consumer demand shifts towards white meats, which helped identify demand factors outside prices and incomes. Robenstein and Thurman (1996) measured the short-term impacts of health concerns, which discovered insignificant effects of Wall Street Journal health-related articles on livestock futures prices.

The literature found more salient evidence by studying food safety information through examining its effects on consumer demand, prices, and volatility. One of the primary studies in this branch of research is by Burton and Young (1996). The authors used media articles and popular press to measure the impact of food safety on beef demand and found a drop in meat market share through an AIDS empirical model. Piggott and Marsh (2004) studied the consumer response to contaminants discovered by the United States Department of Agriculture (USDA), and elasticity measures indicated that food safety information had, on average, a small impact on demand. Marsh, Schroeder, and Mintert (2004) demonstrated that the actual recall reported by USDA had a significant impact on consumer demand while media articles had no effect. Lusk and Schroder (2002) employed an event study methodology to investigate the effects of food recalls on livestock futures. They found that medium-sized recalls of serious health concerns had a significant, adverse effect on live cattle and lean hog returns. Using the same methods, Thomsen and McKenzie (2001) found that *E. coli 0157:H7* recalls had a negative impact on wholesale prices, while Moghadam et al. (2016) confirmed the disease's effects on returns for farm-level returns.

Pozo and Schroeder (2016) used an event study approach to quantify the impact of food recalls in financial markets, concluding a 1.15% drop in shareholder wealth. Salin and Hooker (2001), also, examined capital market response to food recalls. Using a partial-event analysis, they discovered firm size, firm's experience handling a recall, media information and recall size were major variables factoring in the adverse economic impact. Moreover, the study revealed mixed volatility responses for returns. In a follow-up paper, Wang et al. (2002) measured the effects of food recalls on company stock returns and volatility using a generalized autoregressive conditional heteroskedasticity (GARCH) method. They found reduced mean returns and greater volatility for companies that were experiencing their first food recall, and volatility spillovers from those to other companies in the same industry. Therefore, food safety events have been shown to impact financial market returns and volatilities.

Animal Disease Literature

While food recalls have caused considerable costs to the food industry, animal disease outbreaks have caused more substantial economic losses. Following the 2003 U.S. BSE outbreak, beef sales were reduced for approximately three months (Schlenker and Villa-Boas, 2008). Paiva (2003) used an event study approach to examine the impacts of BSE events in the U.K. on the U.S. live cattle market. After aggregating the abnormal returns over the different events, the results showed that the prices were negatively affected after the event day. Also using an event study, Henson and Mazzocchi (2002) examined the effects of different BSE-related events in the U.K. on equity prices for companies in the food industry. Their results indicated significant abnormal returns for various sectors, including beef, pet food, animal feed, and dairy, which suffered considerable revenue losses due to the link established between BSE and human health.

In an analysis of disease outbreaks, Hassouneh et al. (2010) assessed the impact of BSE using a food scare index to quantify the magnitude of price change and resulting transmission following an epidemic. The authors found significant adjustments for producer prices and no changes for consumer prices, confirming earlier studies that found greater variability at farm-level prices as opposed to retail-level. Serra (2011) extended this research by investigating volatility effects on farm and retail markets following a BSE case in Spain. Specifically, the author utilized a Smooth Transition Conditional Correlation (STCC)-GARCH to measure the impact of BSE on price instability along the food supply chain. She found negative correlation between producer and consumer prices during the outbreak. Furthermore, the author found that price stabilization strategies will not work if price volatility in one chain stage does not transmit to another.

Marsh, Brester, and Smith (2008) studied the effects of North American BSE on U.S. fed and feeder cattle, specifically examining the effect of foreign trade bans on prices. The authors concluded that the reactions by foreign governments had a larger impact on prices than the reactions by households. Schlenker and Villa-Boas (2008) examined scanner data following two BSE-related events to understand if prices were more greatly influenced by an actual outbreak or a negative association broadcasted by private media. The results showed abnormal price drops from both sources; however, the drop in shorter contract maturities was more severe for private media. Tse and Hackard (2006) studied herd behavior following the first two North American BSE cases, specifically examining its influence on mispricing. The authors determined that the ambiguity surrounding the two events created mismatches in prices for futures and stock markets, impacting shares of both fast-food restaurants and companies that specialize in testing of contamination detection.

Focusing on the live cattle futures contracts, Jin et al. (2008) studied the impact of sixteen North American BSE cases to find a significant response following the major cases. Specifically, the authors found that the 2003 Canadian and U.S. BSE cases increased volatility of nearby live cattle futures contracts and decreased prices for several months following the events' official announcement. Using a similar method, Attavanich et al. (2011) employed a vector autoregressive model to measure the impact of the 2009 H1N1 flu on agricultural commodity markets. Media articles were found to have an adverse impact on lean hog futures market, while publicity had a minimal effect on related commodities, such as corn, soybeans and live cattle. Overall, the authors concluded that the impact persisted for four months, which resulted in approximately $200 million revenue loss for the pork market. These two studies indicate a growing interest by economists to understand the influence of major animal disease outbreaks on volatility and its impact on related commodities.

Assefa et al. (2015) follow the work of Serra (2011) to analyze the impact of animal disease shocks on commodity price volatility. A primary motivation for their study was the ongoing challenge for not only infected farms, but non-infected farms, to survive a food crisis. The authors use a multivariate GARCH model to analyze volatility transmission from the Spanish to German hog markets. The study indicated that the magnitude of the scare correlated with the degree of volatility response but found no spillover from wheat to hog volatility. This paper contributed to the literature by quantifying the direct volatility impact of food scares and examining the spillover effects from major animal diseases.

Contribution to the Literature

Several studies have cited food safety information as an influence on consumer demand, prices, and other economic variables, specifically, documenting the food safety impacts on returns and volatilities in livestock futures markets. Although authors, such as Serra (2011), have studied the effects of volatility following BSE, her examination only looks at the relationship between producer and retail volatility. On the other hand, while Jin et al. (2008) studied North American volatility effects in futures markets through an extended forecast, a more accurate volatility measure can be obtained by directly modelling the error variance and examining the results through shorter windows.

Our study differs from these previous studies in that, instead of assessing volatility links in retail markets and forecasting futures contract prices, we examine the magnitude of abnormal returns and variance in two livestock futures markets with possible spillover from one market to the other. Furthermore, this study measures the variance of a commodity's futures price following a disease outbreak by directly incorporating the variance of a substitute commodity's futures price. Additionally, because the USDA reports, namely, *Cattle on Feed* and *Hogs and Pigs*, are shown to affect livestock futures volatility in the literature (e.g., Isengildina-Massa et al., 2016) we incorporate the release of these reports in our variance measure. Therefore, this paper gives a more robust account of animal disease effects because it includes all the known factors contributing to variance fluctuations. In the next section, the data are described.

CHAPTER 3

DATA AND SUMMARY STATISTICS

Event Variables

There are two main animal diseases impacting livestock – BSE and the H1N1 flu. Reports from the Centers for Disease Control (CDC) and USDA were gathered to identify the number of cases for each malady and the specific date the agency confirmed positive results. Since 2003, there has been a total of 24 cases of BSE in North America: 20 in Canada and 4 in the United States (CDC, 2015).

Our dataset consists of three BSE cases: the May 20, 2003 Northern Alberta case; the holstein cow case on December 23, 2003 in Washington state; and the July 24, 2012 case in a California dairy cow. Table 1 shows the events and their timelines.[1] We investigate these three cases because prior literature determined that there was no evidence of a significant impact following the other North American BSE outbreaks (Jin et al., 2008).

Table 1. Event timelines

Official Announcement	Disease
05/20/2003	BSE
12/23/2003	BSE
4/24/2009	H1N1
4/24/2012	BSE

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[1] According to Tse and Hackard (2005), the Canadian BSE case was rendered unsafe for consumption in January 2003. Jin et al. (2008) confirmed this by illustrating decreasing live cattle futures prices for three months following January 31, 2003. Therefore, this may have influenced market response during the official announcement.

Furthermore, we would like to capture the impact of animal disease events directly related to the U.S. food supply chain, thus eliminating the other 19 Canadian BSE cases. We also include the 2009 H1N1 flu due to the large economic losses identified in the months following its outbreak (Attavanich et al., 2011). These cases represent highly impactful events, including the first two BSE cases in North America (Canada, May 2003; U.S., December 2003), in addition to the first H1N1 influenza epidemic since 1918.

Livestock Reports

There are two important reports included in the dataset that provide information to market participants: USDA's Cattle on Feed (CF) and Hogs and Pigs (HP) reports. It has been confirmed that futures markets react to these USDA reports (Colling and Irwin, 1990; Grunewald et al., 1993). The CF report consists of information regarding breeding, inventory, marketing, placements, and other disappearances. This report is released monthly and is widely used by market participants to assess their expectations against the actual information contained in the report. Hogs and Pigs report serves a similar purpose in that it reveals inventory, value of hogs and pigs, and farrowing. We incorporate dummy variables indicating these reports' release days from 1990 through 2016 as independent variables in variance estimation. If a report was released before or during trading hours, then the report's dummy variable takes the value of one on that day. If the report was released after trading hours, then the dummy variable takes the value of one on the following trading day.

Futures Prices

Livestock futures contracts are traded at the CME Group. Live cattle and lean hog contracts both represent financial instruments for live animals ready for slaughter. Each live cattle futures contract is for 40,000 pounds. Feeder cattle and live cattle make up the primary contracts for beef trading. They differ in that the latter is for animals ready for packers. Specifically, buyers of live cattle contracts, if they're not engaging in speculation, typically intend on buying cattle at this stage of development because the animal is ready for processing. Therefore, it is reasoned that market events suspected to directly affect the food supply chain will most severely impact contracts representing these live animals. Lean hog contracts represent pork that is ready for slaughter and processing. The CME lists individual contract size as 40,000 pounds and serves producers and consumers seeking risk management practices.

Each futures contract has various maturity months. Contract months are February, April, June, August, October, and December for live cattle, and February, April, May, June, July, August, October, and December for lean hogs.

Table 2. Contracts used in empirical analysis

	Live Cattle (LC)		Lean Hogs (LH)	
Calendar Month	Nearby Futures	Deferred Futures	Nearby Futures	Deferred Futures
January$_t$	February$_t$	August$_t$	February$_t$	August$_t$
February$_t$	April$_t$	October$_t$	April$_t$	October$_t$
March$_t$	April$_t$	October$_t$	April$_t$	October$_t$
April$_t$	June$_t$	December$_t$	June$_t$	December$_t$
May$_t$	June$_t$	December$_t$	June$_t$	December$_t$
June$_t$	August$_t$	February$_{t+1}$	July$_t$	February$_{t+1}$
July$_t$	August$_t$	February$_{t+1}$	August$_t$	February$_{t+1}$
August$_t$	October$_t$	April$_{t+1}$	October$_t$	April$_{t+1}$
September$_t$	October$_t$	April$_{t+1}$	October$_t$	April$_{t+1}$
October$_t$	December$_t$	June$_{t+1}$	December$_t$	June$_{t+1}$
November$_t$	December$_t$	June$_{t+1}$	December$_t$	July$_{t+1}$
December$_t$	February$_{t+1}$	August$_{t+1}$	February$_{t+1}$	August$_{t+1}$

Notes. The subscript, t or t + 1, refers to the year of the futures contract expiration date relative to the year t of the daily price being computed. Listed contract months for live cattle are February, April, June, August, October, and December. Contract months for lean hogs are February, April, May, June, July, August, October, and December. The nearby and distant futures series are constructed using those contracts expiring 1 to 2 months and 7 to 8 months, respectively. May contracts for lean hogs are excluded due to low volume.

Table 2 presents specific contract months used in constructing the nearby and deferred futures series for each commodity. In analyzing futures data, identifying nearby and deferred contract months is important because past research has determined that contracts closer to expiration are affected differently than contracts farther from expiration. For instance, Frank et al. (2008) found this to be true when investigating the effects of market information, such as cattle and hog reports, on live cattle and lean hog prices. Following Frank et al. (2008), we define contract time horizons as contracts expiring in 2 to 3 months to represent nearby contracts, and in 7 to 8 months to represent deferred contracts.

Our dataset consists of daily settlement prices of live cattle and lean hog futures contracts from January 3, 2000 through December 30, 2016. After removing federal holidays and other non-trading days, a total of 4,279 observations are obtained. Daily returns are calculated as

$$R_t = 100 \times \ln(P_t/P_{t-1}), \tag{1}$$

where P_t represents the settlement price on day t. Figure 1 illustrates nearby live cattle futures returns for the sample period. It can be seen from the graph that the mean is constant through time; however, there is time-varying volatility.

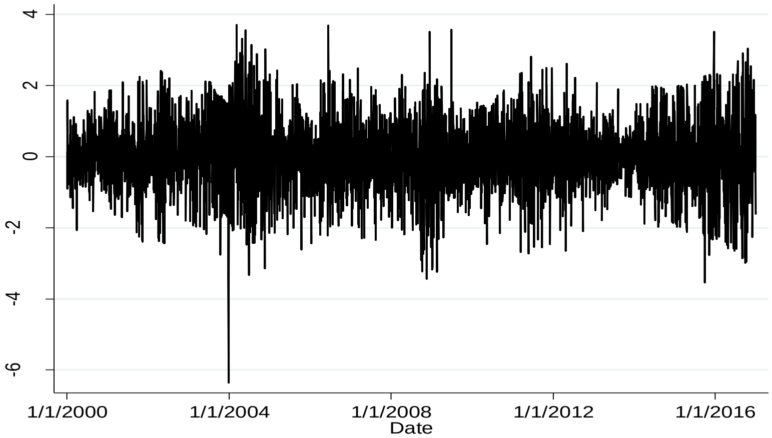

Figure 1: Returns for nearby live cattle futures contracts

Although it is difficult to distinguish specific events from the graph, it is obvious that there are clusters of increased volatility in live cattle markets. Figure 2 represents nearby lean hog futures returns. Similar to live cattle returns, the mean seems constant and the variance fluctuates over time. According to the graph, there is increased volatility in 2002/2003. The lean hog returns display more volatile behavior compared to live cattle returns.

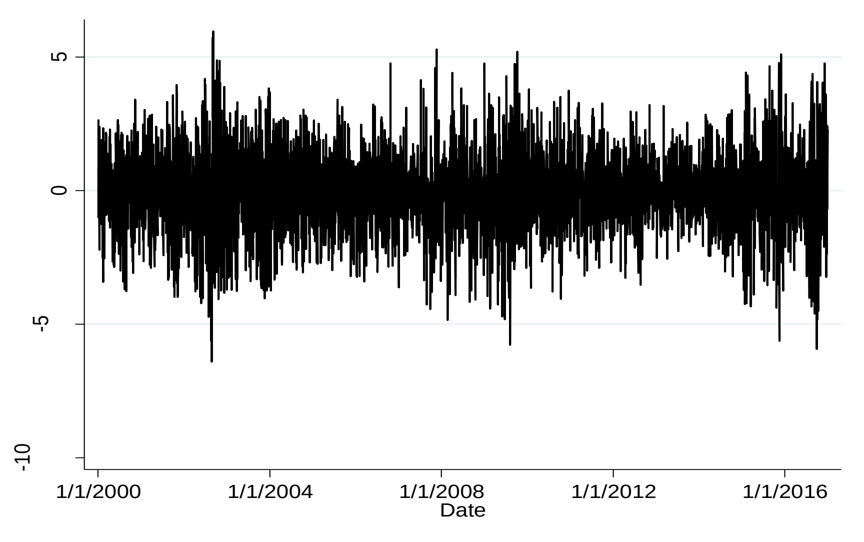

Figure 2: Returns for nearby lean hog futures contracts

Table 3 presents summary statistics for the daily returns and absolute returns on nearby and deferred livestock futures contracts. The average return was nearly zero for live cattle nearby contracts, while the absolute returns registered a .7 (.71%) mean value. The summary statistics indicate that the average daily returns for lean hogs, on the other hand, were negative and registered a greater magnitude in absolute returns than live cattle. Table 4 summarizes the diagnostic test results. An augmented Dickey-Fuller (ADF) test indicates that the returns for both commodities are stationary. The lag selection for the ADF tests were chosen by Akaike information criterion (AIC).

Table 3. Summary statistics of live cattle and lean hog returns

Variable	$R_t = 100 \times \ln(P_t/P_{t-1})$				
	# of Obs.	Mean	Std. Dev.	Min	Max
Nearby					
LC	4,279	0.002	0.948	-6.357	3.708
LH	4,279	-0.023	1.488	-6.407	5.963
Deferred					
LC	4,279	0.023	1.039	-4.948	4.909
LH	4,279	0.008	0.703	-4.182	3.477
Variable	$\lvert R_t \rvert = \lvert 100 \times \ln(P_t/P_{t-1}) \rvert$				
	# of Obs.	Mean	Std. Dev.	Min	Max
Nearby					
LC	4,279	0.707	0.631	0.000	6.357
LH	4,279	1.130	0.969	0.000	6.407
Deferred					
LC	4,279	0.509	0.485	0.000	4.182
LH	4,279	0.765	0.703	0.000	4.948

Table 4. Diagnostic tests for nearby & deferred contracts

Test	Live Cattle Nearby		Lean Hog Nearby	
	R_t	$\lvert R_t \rvert$	R_t	$\lvert R_t \rvert$
Augmented Dickey-Fuller	-20.712	-18.486	-21.631	-22.149
	(<0.000)	(<0.000)	(<0.000)	(<0.000)
Ljung-Box	79.088	1128.5	39.802	1005
	(<0.000)	(<0.000)	(<0.000)	(<0.000)
ARCH Effects	180.348	293.266	34.288	28.883
	(<0.000)	(<0.000)	(<0.000)	(<0.000)
Test	Live Cattle Deferred		Lean Hog Deferred	
	R_t	$\lvert R_t \rvert$	R_t	$\lvert R_t \rvert$
Augmented Dickey-Fuller	-83.61	-70.711	-79.157	-67.91
	(<0.000)	(<0.000)	(<0.000)	(<0.000)
Ljung-Box	35.943	2362.7	50.955	1046.6
	(<0.000)	(<0.000)	(<0.000)	(<0.000)
ARCH Effects	346.132	149.134	161.017	230.296
	(<0.000)	(<0.000)	(<0.000)	(<0.000)

Note: the null hypothesis for the ADF test is that a unit root is present. The Ljung-Box test tests the null hypothesis of no serial correlation. The null hypothesis of ARCH effects is no ARCH effects.

The Ljung-Box test shows that the returns are serially correlated. Finally, we test for ARCH effects to see if the squared returns exhibit autocorrelation and reject the null hypothesis of no ARCH effects, indicating existence of heteroskedasticity in the variance process for both contract maturities.

Preliminary Analysis

To better examine the data over the disease outbreaks, figure 3 illustrates both nearby and deferred contracts for live cattle returns. There are four dashed lines representing the four diseases being studied. Specifically, the largest decrease in cattle returns occurs nearly identical to the vertical line representing the 2003 U.S. BSE case. The period surrounding the Canadian case is shrouded with high degrees of fluctuations, however, magnitude is at its height following the December 2003 outbreak in Washington.

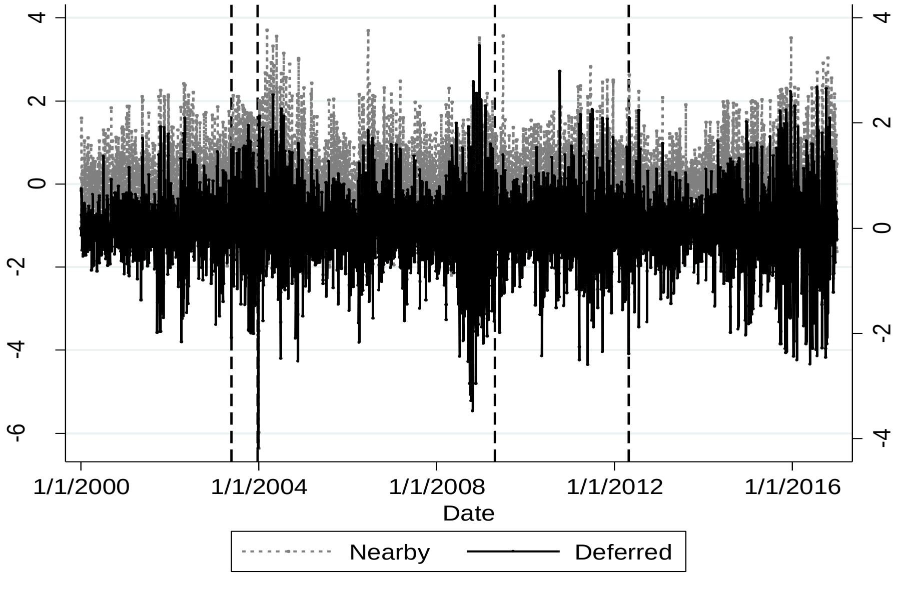

Figure 3: Returns for nearby and deferred live cattle futures

Tse and Hackard (2005) stated that the Canadian BSE case was rendered unsafe for consumption in January 2003, potentially leaking BSE information before the event, thus causing increased volatility before the actual confirmation. Indeed, Jin et al. (2008) observed a three month decrease in live cattle futures prices from January to March 2003. More importantly, the graph shows that both maturities behave similarly with relatively stronger movements in nearby contracts than deferred.

Figure 4 displays lean hog returns for nearby and deferred contracts. Lean hogs maturities behave similarly to live cattle in that there are relatively smaller fluctuations for deferred contracts.

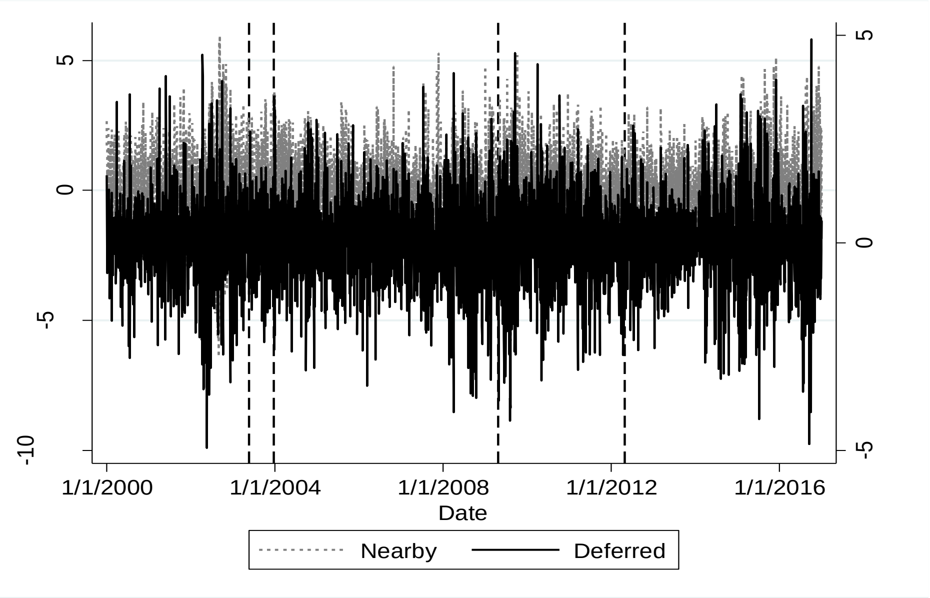

Figure 4: Returns for nearby and deferred lean hog futures

The empirical analysis aims to identify whether these magnitudes are statistically related by the 2009 H1N1 flu and BSE outbreaks. The time period of interest for lean hogs, 2009, has elevated levels of volatility, which may correspond to April 24, 2009.

Immediately following the 2009 event, volatility levels increase for an undetermined period. Part of these results could signify a response to market uncertainty concerning food outbreaks from other commodities, which the analysis will measure.

CHAPTER 4

EMPIRICAL METHODOLOGY

This paper follows the two-step methodology developed by Andersen and Bollerslev (1998) to examine the impact of disease outbreaks on futures market returns and volatility. The first step is to estimate the mean of futures returns. Squared predicted residuals obtained from this step are used to fit a linear variance model in the second step. The fitted variance is then used in a weighted least squares (WLS) framework to correct for heteroskedasticity in the standard errors of the parameter estimates in the mean equation.

Return Model

We model the livestock futures return, R_t, as follows:

$$R_t = \alpha + \sum_{p=1}^{P} \phi_p R_{t-p} + \beta_1 CN2003_t + \beta_2 US2003_t + \beta_3 US2012_t + \beta_4 H1N1_t + \varepsilon_t, \tag{2}$$

where R_t is the continuously compounded return computed as in equation (1). Based on the AIC criteria, the lag length of P = 1 is chosen for nearby and deferred live cattle and nearby lean hog futures returns, while P = 3 is chosen for deferred lean hog futures returns.

Each outbreak event is represented by a dummy variable. Rather than a classical event study approach, we use a regression framework to measure abnormal returns as regression coefficients (MacKinlay, 1997; Binder, 1998). The event dummy variables are created for different event windows, to examine the outbreak impacts on returns and volatility over different time intervals. For example, an event dummy variable with the event window [0, 5] takes the value of one on the day of the event and on the following five trading days. The event windows [0, 5], [0, 10], [0, 15], and [0, 30] are considered for a comprehensive analysis of the average short-term and long-term impacts.

We estimate the above equation by ordinary least squares (OLS) for each commodity's nearby and deferred futures returns separately and obtain the predicted residuals, $\hat{\varepsilon}_t$. Following Andersen et al. (2003), we approximate the time-varying variance of these residuals by a linear model explained below to use in the WLS estimation of equation (2).

Variance Model

We model the time-varying variance as:

$$\begin{aligned}\hat{\varepsilon}_t^2 = \mu + \lambda_1 CF_t + \lambda_2 HP_t + \delta_1 CN2003_t + \delta_2 US2003_t + \delta_3 US2012_t + \delta_4 H1N1_t \\ + \eta_1 Mon_t + \eta_2 Tue_t + \eta_3 Wed_t + \eta_4 Thu_t + \psi_1 Q1_t + \psi_2 Q2_t + \psi_3 Q3_t \\ + \zeta \hat{\varepsilon}_{\ell,t-1}^2 + \theta \hat{\varepsilon}_{t-1}^2 + \gamma \omega_{t-1} + \omega_t,\end{aligned} \tag{3}$$

where $\hat{\varepsilon}_t^2$, is the squared residuals from equation (2) and is modeled as ARMA (1, 1) to capture the effect of last period's variance and the persistence observed after the outbreaks. The outbreak dummy variables are defined the same way as in equation (2). The dummy variables CF_t and HP_t indicate the Cattle on Feed and Hogs and Pigs reports, respectively. Weekly effects are incorporated with weekday dummy variables for Monday through Thursday, treating Friday as the baseline. The variables $Q1_t$, $Q2_t$, and $Q3_t$ are quarterly seasonal dummies to model the cyclical behavior with fourth quarter being the reference period.

In equation (3), we represent spillover effects by $\hat{\varepsilon}_{\ell,t-1}^{2}$where ℓ identifies the substitute commodity. More specifically, the lagged estimated variance of lean hog returns are included in the variance equation of live cattle returns to account for spillover effects from one commodity to another.

CHAPTER 5

RESULTS

Return Model

In this section, the results are presented for the return models. The estimated parameters illustrate the abnormal returns around different disease outbreaks. The results illustrate the average abnormal returns for horizons ranging from five to thirty trading days following an outbreak.

Nearby Futures Contracts

Table 5 presents coefficient estimates for nearby live cattle returns. The autoregressive coefficient indicates positive and significant serial correlation in the daily returns. The only event with a significant reaction was the 2003 BSE case in the U.S.

Table 5. Live cattle returns for nearby contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	0.000	-0.001	0.000	-0.001
	(0.991)	(0.923)	(0.974)	(0.947)
R_{t-1}	0.040***	0.042***	0.045***	0.045***
	(0.011)	(0.008)	(0.004)	(0.005)
CN2003	0.240	0.249	-0.029	0.089
	(0.574)	(0.397)	(0.917)	(0.607)
US2003	-3.222***	-1.573**	-0.848	-0.497
	(0.001)	(0.051)	(0.187)	(0.208)
US2012	-0.192	0.073	0.077	0.060
	(0.710)	(0.856)	(0.797)	(0.743)
H1N1	-0.263	-0.009	-0.064	-0.141
	(0.486)	(0.971)	(0.740)	(0.222)

Note: The parameter estimates from weighted least square estimation of the return equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The event window [0, 5] measures average abnormal returns over six trading days – the event day and five trading days after the event – with a drop of -3.222. As the event window is extended, the impact diminishes, registering insignificant results for periods of fifteen trading days or over.

The regression results for lean hog returns during disease outbreaks are presented in Table 6. There is a drop in returns by a magnitude of 1.474, on average, over six total trading days during the H1N1 outbreak.

Table 6. Lean hog returns for nearby contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	-0.025	-0.026	-0.025	-0.025
	(0.237)	(0.215)	(0.232)	(0.237)
R_{t-1}	0.013	0.015	0.015	0.013
	(0.405)	(0.341)	(0.347)	(0.400)
CN2003	-0.714	-0.169	-0.297	-0.231
	(0.124)	(0.606)	(0.293)	(0.267)
US2003	0.031	0.125	0.027	0.361
	(0.974)	(0.857)	(0.961)	(0.271)
US2012	-0.432	-0.331	-0.071	0.169
	(0.274)	(0.287)	(0.777)	(0.391)
H1N1	-1.474*	-0.474	-0.536	-0.765**
	(0.083)	(0.520)	(0.314)	(0.017)

Note: The parameter estimates from weighted least square estimation of the return equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The impact abates as the event window increases; however, returns significantly decreased by a magnitude of 0.765 when the post-event horizon is extended to thirty trading days. These results are intuitive since abnormal returns occur in live cattle during BSE events, while hog returns are adversely experienced throughout 2009 H1N1 flu epidemic.

Deferred Futures Contracts

Next, we analyze the impacts of disease outbreaks on deferred contract maturities. By examining the magnitude of effects on nearby and deferred contracts, we can determine how different diseases impacted commodities in different stages of development. Deferred contracts represent underdeveloped cattle and hogs not ready for slaughter. However, it reflects what market participants believe the price will be in that particular month. For example, if the price of a contract nine months out is impacted, then that drop reflects what market participants forecast the price to be in nine months, suggesting that the event will be non-transitory.

Table 7. Live cattle returns for deferred contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	0.007	0.005	0.005	-0.059***
	(0.448)	(0.562)	(0.556)	(0.000)
R_{t-1}	-0.009	-0.009	-0.008	-0.158***
	(0.567)	(0.583)	(0.645)	(0.000)
CN2003	0.101	0.118	-0.058	0.099
	(0.830)	(0.695)	(0.807)	(0.495)
US2003	-1.385**	-0.224	-0.091	-0.060
	(0.016)	(0.670)	(0.818)	(0.817)
US2012	-0.336	-0.016	-0.063	0.077
	(0.456)	(0.963)	(0.798)	(0.638)
H1N1	-0.158	0.068	0.066	-0.039
	(0.604)	(0.740)	(0.669)	(0.742)

Note: The parameter estimates from the weighted least squares estimation of the return equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7 identifies reduced returns during the first BSE outbreak in the U.S. Live cattle were most greatly impacted the first five days following the outbreak confirmation, with average abnormal returns measuring 1.385 during this period. On the other hand, the other events had no effect on prices. Lean hog returns for deferred contracts, displayed in Table 8, shows insignificant results for all event window lengths. Comparing these results to nearby contracts, the market showed a greater response to contracts closer to expiration, potentially signifying that market participants holding older, more developed livestock – or financial instruments representing livestock at this stage – suffered the greatest losses. According to the results, the returns behaved differently for each event. In the only event with significant abnormal returns, the nearby contracts were far more significantly affected.

Table 8. Lean hog returns for deferred contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	0.022	0.021	0.022	0.02
	(0.122)	(0.147)	(0.126)	(0.168)
R_{t-1}	0.017	0.017	0.016	0.018
	(0.314)	(0.302)	(0.328)	(0.269)
R_{t-2}	-0.023	-0.022	-0.021	-0.02
	(0.159)	(0.174)	(0.198)	(0.213)
R_{t-3}	-0.013	-0.013	-0.013	-0.014
	(0.419)	(0.410)	(0.421)	(0.389)
CN2003	0.216	0.163	-0.062	0.015
	(0.670)	(0.606)	(0.790)	(0.924)
US2003	-0.351	0.236	0.129	0.024
	(0.648)	(0.682)	(0.753)	(0.917)
US2012	-0.294	-0.289	-0.138	0.064
	(0.296)	(0.243)	(0.537)	(0.666)
H1N1	-0.420	0.073	-0.180	-0.129
	(0.578)	(0.885)	(0.635)	(0.592)

Note: The parameter estimates from the weighted least squares estimation of the return equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Figure 5 illustrates the point estimates for the average abnormal returns during the [0, 5] window with 95% confidence intervals. All contracts are abbreviated with four letters representing the maturity (NB for nearby and DF for deferred) and commodity (LC for live cattle and LH for lean hogs). For example, NBLC and DFLH refer to nearby live cattle and deferred lean hog contracts, respectively. According to figure 5, abnormal returns were only experienced during the 2003 U.S. BSE and 2009 H1N1 outbreaks. Although both live cattle contracts were affected, the abnormal return is greater in magnitude for nearby contracts.

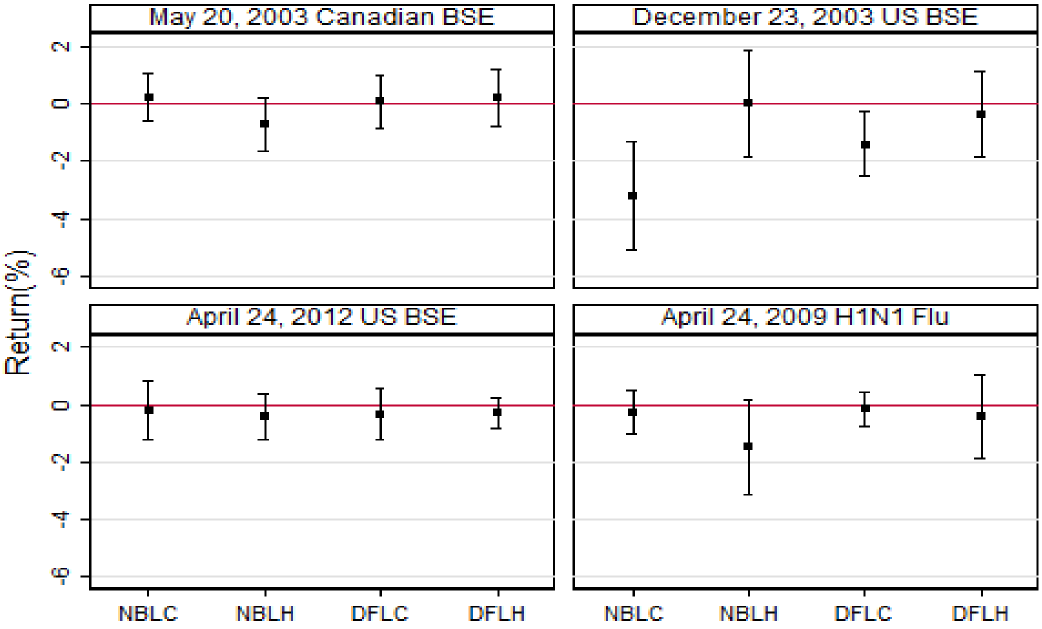

Figure 5: Returns for event window [0, 5] with 95% confidence intervals

Figure 6 presents a graphical representation of abnormal returns across different event windows. In each subfigure each outbreak has four lines showing the abnormal returns obtained from event windows [0, 5], [0, 10], [0, 15], and [0, 30], respectively. This figure supports the aforementioned findings that the greatest response occurred in the shorter windows. However, abnormal returns became significant for lean hog nearby contracts when the time horizon was extended to 30 days following the H1N1 outbreak.

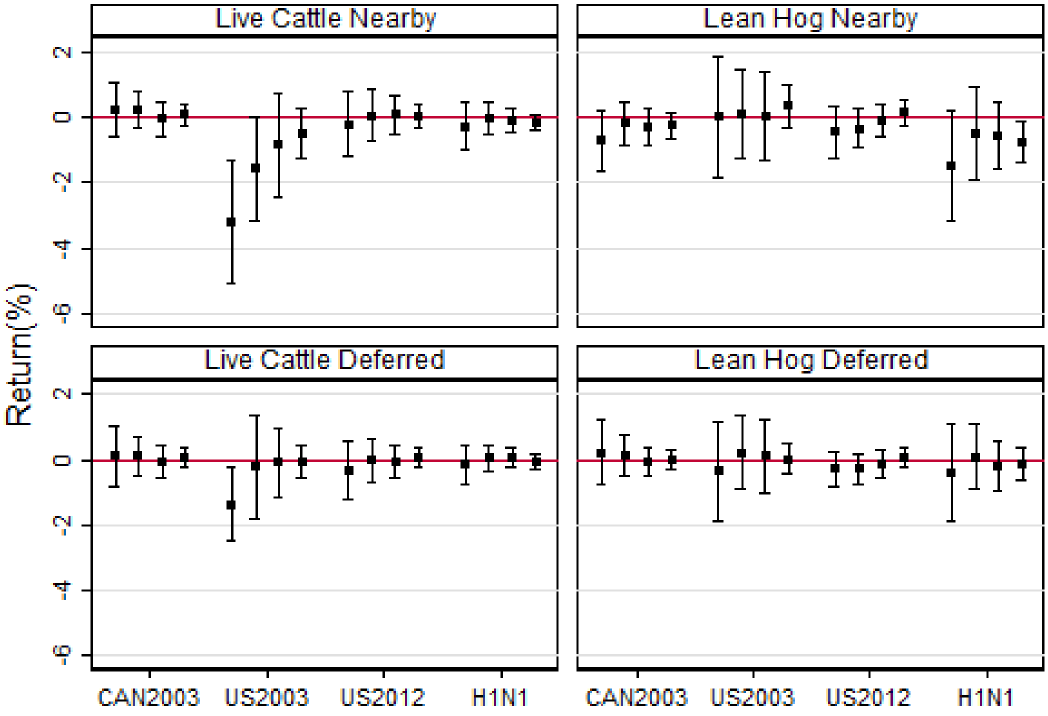

Figure 6: Comparison of returns across event windows with 95% confidence intervals

Variance Model

In this section, the results from the variance model for live cattle and lean hog are presented.

Nearby Futures Contracts

In Table 9, the autoregressive and moving average terms are highly significant at the 1% level. In addition, the Hog and Pigs report is significant in all time horizons with the abnormal variance increasing from approximately 0.253 to 0.312 from the shortest to longest window. Furthermore, the BSE events in 2003 and 2012 showed statistically significant results with variance reaching its highest magnitude during the 2003 U.S. mad cow scare. The variance, on average, increased the most during the [0, 10] horizon for both events. For the 2012 food scare, the magnitude of abnormal variance increased in all post-event horizons not exceeding fifteen days. While the abnormal variance plateaued at 0.919 during the 2012 case, the variance increased by 5.791

during the same event window of [0, 10] for the 2003 outbreak, illustrating how the first BSE discovery had a more severe impact on markets than the same disease occurring nine years later.

Table 9. Live cattle variance for nearby contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	0.856***	0.866***	0.902***	0.931***
	(0.000)	(0.000)	(0.000)	(0.000)
CF	0.123	0.108	0.118	0.112
	(0.272)	(0.342)	(0.318)	(0.369)
HP	0.253**	0.238**	0.292**	0.312**
	(0.029)	(0.049)	(0.026)	(0.034)
CN2003	0.424	0.275	0.583	0.105
	(0.307)	(0.467)	(0.160)	(0.770)
US2003	4.062***	5.791***	5.098***	3.404***
	(0.000)	(0.000)	(0.000)	(0.000)
US2012	0.697*	0.919***	0.526*	0.129
	(0.071)	(0.000)	(0.063)	(0.653)
H1N1	-0.206	-0.327	-0.471	-0.640
	(0.863)	(0.773)	(0.638)	(0.343)
Mon	0.044	0.060	0.049	0.054
	(0.598)	(0.479)	(0.574)	(0.552)
Tue	0.001	-0.010	-0.007	0.004
	(0.986)	(0.894)	(0.928)	(0.959)
Wed	0.118*	0.116	0.118	0.120
	(0.092)	(0.106)	(0.118)	(0.130)
Thu	0.141**	0.132*	0.132*	0.132*
	(0.046)	(0.068)	(0.080)	(0.089)
Q1	-0.052	-0.090	-0.172*	-0.255**
	(0.608)	(0.329)	(0.076)	(0.020)
Q2	0.011	-0.015	-0.064	-0.088
	(0.920)	(0.889)	(0.555)	(0.474)
Q3	-0.095	-0.108	-0.135	-0.156
	(0.295)	(0.232)	(0.147)	(0.138)
$\hat{\varepsilon}^2_{\ell,t-1}$	-0.011*	-0.007	-0.006	-0.006
	(0.095)	(0.277)	(0.357)	(0.383)
$\hat{\varepsilon}^2_{t-1}$	0.994***	0.002***	0.994***	0.990***
	(0.000)	(0.000)	(0.000)	(0.000)
ω_{t-1}	-0.960***	0.004***	-0.963***	-0.952***
	(0.000)	(0.000)	(0.000)	(0.000)

Note: The parameter estimates from the variance equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 9, also, shows the spillover effect from lean hog to live cattle in the [0, 5] event window. This indicates that the lean hog variance decreases the live cattle variance, reducing it by a magnitude of approximately 0.011. A potential reason for this is that possible changes in returns for lean hogs could increase certainty in live cattle markets, thus reducing the variance and stabilizing returns. Instances where this may unfold is when a market disruption increases the substitute commodity’s demand. The result remained mostly the same when the horizon was increased to thirty days, however, the abnormal variance abated for the 2012 event. When the window was adjusted to measure leakage effects, the magnitude of average abnormal variance increased in US2003, suggesting that information may have been available to market participants prior to the official announcement.

Table 10 shows the results for nearby lean hog variance. It indicates that the variance was statistically impacted by the Hogs and Pigs reports at the 10% level, increasing the average fluctuations by approximately 0.700. The variance is comparatively smaller in the second quarter, while Tuesday registered increased effects. The variance increased during two events, 2003 BSE and 2009 H1N1 flu, using both [0, 10] and [0, 15] event windows. Abnormal variance measures were approximately 1.500 for both horizons. Time horizon [0, 15] displayed the highest significance (5%) and increased the variance by 1.499, on average, during these trading days. While the variance increased for the BSE case during this period, abnormal variance estimates were larger during the 2009 H1N1 flu. The greatest increase in the variance happened in event window [0, 10], where there was a 4.278 increase in the lean hog variance for the eleven-day trading period. The results indicate no spillover effect from the live cattle variance to the lean hog variance. When the time horizon was extended to thirty days, the H1N1 outbreak was the only event where abnormal variance levels were experienced. Otherwise, the Hog and

Pigs reports, quarterly and weekday seasonality, and the ARMA terms sustained explanatory power.

Table 10: Lean hog variance for nearby contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	2.297***	2.313***	2.328***	2.330***
	(0.000)	(0.000)	(0.000)	(0.000)
CF	-0.170	-0.169	-0.171	-0.183
	(0.593)	(0.594)	(0.591)	(0.562)
HP	0.695*	0.706*	0.704*	0.721**
	(0.058)	(0.054)	(0.055)	(0.050)
CN2003	-0.585	-0.823	-0.621	-0.705
	(0.847)	(0.792)	(0.776)	(0.642)
US2003	1.224	1.502*	1.499**	-0.017
	(0.184)	(0.055)	(0.041)	(0.979)
US2012	-0.777	-0.605	-0.667	-0.380
	(0.911)	(0.902)	(0.861)	(0.868)
H1N1	2.793	4.278***	2.493***	1.049*
	(0.132)	(0.000)	(0.001)	(0.101)
Mon	0.024	0.032	0.028	0.026
	(0.904)	(0.869)	(0.886)	(0.896)
Tue	0.310*	0.326**	0.324*	0.323*
	(0.063)	(0.051)	(0.053)	(0.054)
Wed	0.245	0.250	0.242	0.248
	(0.143)	(0.135)	(0.149)	(0.138)
Thu	-0.040	-0.025	-0.032	-0.034
	(0.826)	(0.890)	(0.860)	(0.853)
Q1	-0.245	-0.258	-0.273	-0.271
	(0.352)	(0.330)	(0.307)	(0.309)
Q2	-0.572*	-0.585**	-0.583*	-0.576*
	(0.055)	(0.051)	(0.053)	(0.057)
Q3	-0.145	-0.158	-0.160	-0.159
	(0.495)	(0.460)	(0.455)	(0.457)
$\hat{\varepsilon}^2_{\ell,t-1}$	0.051	0.028	0.022	0.024
	(0.140)	(0.405)	(0.503)	(0.473)
$\hat{\varepsilon}^2_{t-1}$	0.992***	0.991***	0.991***	0.991***
	(0.000)	(0.000)	(0.000)	(0.000)
ω_{t-1}	-0.956***	-0.955***	-0.955***	-0.955***
	(0.000)	(0.000)	(0.000)	(0.000)

Note: The parameter estimates from the variance equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

There was a qualitative change in the data when the horizon included two trading days before the 2003 US BSE event. In all horizons, the magnitude was significant and greater, suggesting market participants were responding to information before the announcement.

Deferred Futures Contracts

The results presented in Table 11 reveal meaningful information about the deferred contracts for live cattle. While the Hogs and Pigs report was significant for the nearby contracts, the same report had no effect on the variance of deferred futures returns. Instead, Cattle on Feed registered significant results in all time horizons, increasing the variance by 0.142 at its greatest influence in time horizon [0, 15]. Furthermore, the Canadian BSE outbreak went from being inconsequential in all previous results, to highly significant in time horizons [0, 5], [0, 10], and [0, 15]. In horizon [0, 5] the variance increased by 0.962. During the 2003 U.S. BSE outbreak, the variances were impacted for deferred contracts, specifically increasing the average magnitude by 2.407 for event window [0, 10]. This disease had a positive impact on the variance in all horizons with a strong statistical significance. As for the 2012 case, variances decrease in all models, except event window [0, 15] in which case the fluctuations increased. Spillover effects were identified in the two longer periods with the variance of lean hogs increasing the variance of live cattle by approximately .008 and .009 in event windows [0, 15] and [0, 30], respectively. The autoregressive and moving average terms are highly significant in all models, illustrating the effect that the past values of the variance and the persistence observed after the outbreaks.

The results presented in Table 12 show the coefficient estimates for the deferred series on lean hogs. First, the Hogs and Pigs report was effective in explaining some of the variation in return variance, and there was seasonality present in the third quarter. The autoregressive and moving average components had explanatory power, signifying the impact of the previous error variance on current variance fluctuations.

Table 11. Live cattle variance for deferred contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	0.524***	0.540***	0.551***	0.554***
	(0.000)	(0.000)	(0.000)	(0.000)
CF	0.136**	0.139**	0.142**	0.135*
	(0.039)	(0.043)	(0.041)	(0.053)
HP	0.106	0.075	0.089	0.091
	(0.204)	(0.377)	(0.297)	(0.293)
CN2003	0.962***	0.660***	0.598***	0.158
	(0.000)	(0.000)	(0.006)	(0.399)
US2003	1.310***	2.407***	1.862***	1.287***
	(0.000)	(0.000)	(0.000)	(0.000)
US2012	0.720***	0.751***	0.447***	0.190
	(0.003)	(0.000)	(0.007)	(0.218)
H1N1	-0.013	-0.327	-0.202	-0.152
	(0.985)	(0.866)	(0.720)	(0.738)
Mon	0.021	0.013	0.010	0.012
	(0.661)	(0.788)	(0.849)	(0.807)
Tue	-0.007	-0.018	-0.019	-0.016
	(0.872)	(0.690)	(0.676)	(0.725)
Wed	0.024	0.016	0.016	0.018
	(0.620)	(0.750)	(0.742)	(0.725)
Thu	0.028	0.020	0.018	0.019
	(0.554)	(0.677)	(0.707)	(0.697)
Q1	-0.079	-0.109	-0.136*	-0.150*
	(0.284)	(0.150)	(0.076)	(0.054)
Q2	-0.081	-0.099	-0.115	-0.118
	(0.318)	(0.231)	(0.170)	(0.167)
Q3	-0.128**	-0.137**	-0.144**	-0.147**
	(0.036)	(0.027)	(0.021)	(0.020)
$\hat{\varepsilon}^2_{\ell,t-1}$	0.005	0.007	0.008*	0.009*
	(0.337)	(0.155)	(0.102)	(0.087)
$\hat{\varepsilon}^2_{t-1}$	0.992***	0.992***	0.992***	0.991***
	(0.000)	(0.000)	(0.000)	(0.000)
ω_{t-1}	-0.945***	-0.948***	-0.948***	-0.945***
	(0.000)	(0.000)	(0.000)	(0.000)

Note: The parameter estimates from the variance equation are presented. The p-values are in parentheses and *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The variance of returns was highly significant and increased during two events: U.S. BSE 2003 and 2009 H1N1 flu. During the 2003 U.S. BSE case the abnormal variance was 2.290 in horizon [0, 10] at its peak and continued to register significant responses for thirty trading days following the event.

Table 12. Lean hog variance for deferred contracts

	[0, 5]	[0, 10]	[0, 15]	[0, 30]
Intercept	0.743***	0.747***	0.748***	0.745***
	(0.000)	(0.000)	(0.000)	(0.000)
CF	0.105	0.104	0.109	0.099
	(0.525)	(0.527)	(0.508)	(0.544)
HP	2.129***	2.162***	2.171***	2.173***
	(0.000)	(0.000)	(0.000)	(0.000)
CN2003	0.959	0.234	0.013	-0.161
	(0.336)	(0.790)	(0.987)	(0.833)
US2003	2.222***	2.290***	1.513***	0.756**
	(0.000)	(0.000)	(0.000)	(0.041)
US2012	-0.832	-0.512	-0.278	-0.478
	(0.882)	(0.830)	(0.870)	(0.753)
H1N1	2.336***	1.625***	1.178***	0.653**
	(0.000)	(0.000)	(0.001)	(0.049)
Q1	0.227	0.190	0.183	0.183
	(0.232)	(0.317)	(0.331)	(0.326)
Q2	0.280	0.271	0.277	0.294**
	(0.110)	(0.119)	(0.109)	(0.086)
Q3	0.396***	0.393***	0.400***	0.408***
	(0.011)	(0.011)	(0.010)	(0.009)
Mon	0.005	0.015	0.007	0.008
	(0.965)	(0.898)	(0.953)	(0.943)
Tue	0.039	0.049	0.048	0.047
	(0.683)	(0.606)	(0.616)	(0.620)
Wed	0.045	0.058	0.058	0.058
	(0.664)	(0.575)	(0.577)	(0.575)
Thu	-0.062	-0.054	-0.059	-0.060
	(0.562)	(0.610)	(0.580)	(0.571)
$\hat{\varepsilon}^2_{\ell,t-1}$	0.078***	0.072***	0.074***	0.074***
	(0.000)	(0.000)	(0.003)	(0.003)
$\hat{\varepsilon}^2_{t-1}$	0.961***	0.956***	0.950***	0.943***
	(0.000)	(0.000)	(0.000)	(0.000)
ω_{t-1}	-0.894***	-0.885***	-0.872***	-0.861***
	(0.000)	(0.000)	(0.000)	(0.000)

Note: The parameter estimates from ARMA estimation of the return Eq. (3). P-values are in parenthesis and *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

As for the 2009 H1N1, the variance was significantly elevated in all time horizons, increasing the most by 2.336 in the shortest post-event horizon. The spillover effects had an impact in all horizons with an approximate 0.070 increase in the variance. In contrast to the return results, the variance measures had more considerable responses during the disease outbreaks. Figure 7 illustrates the point estimates for the abnormal variance estimates in event window [0, 5] with 95% confidence intervals.

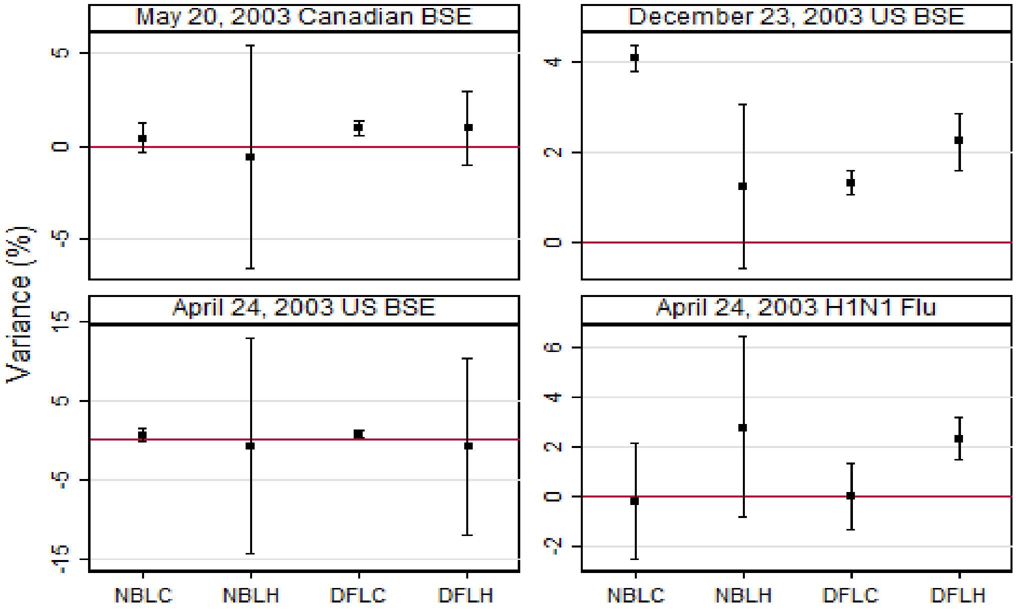

Figure 7: Variance estimates for event window [0, 5] with 95% confidence intervals

According to the results, abnormal variances were experienced during each outbreak. Despite there being insignificant responses for returns during the Canadian BSE case, the variances registered abnormal reactions for deferred contracts. Overall, deferred contracts were significant across more events, showing variance increases during all outbreaks studied. However, nearby contracts had a greater magnitude with the abnormal variance measuring 4.062 throughout the five days surrounding the outbreak.

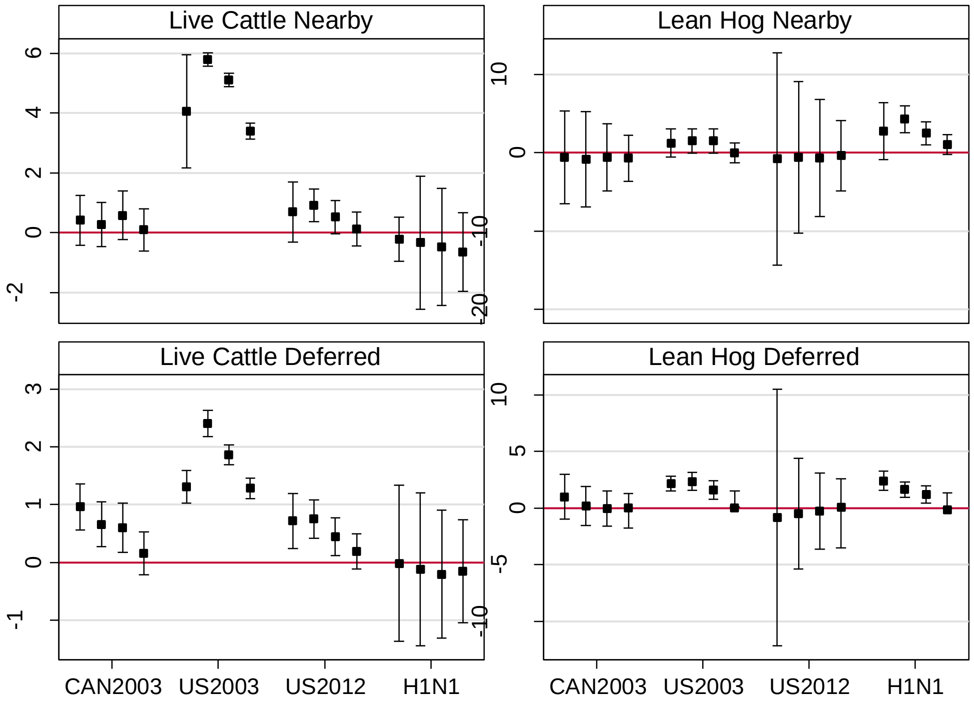

Figure 8: Comparison of variances across event windows with 95% confidence intervals

Figure 8 presents a graphical representation of average abnormal variances across different event windows. As shown in the graphs, the greatest abnormal variances were registered during the second event window, [0, 10], for most events, especially with the BSE cases. Furthermore, what can be seen from the graphs is that financial markets incorporated the new information fairly efficiently, resulting in abnormal variances diminishing over time.

CHAPTER 6

CONCLUSIONS

Overall, livestock futures markets are affected during animal disease outbreaks. Abnormal returns and variances for contracts of different maturities were found during shorter trading windows following the announcement of the food scares studies. This was true for all events, except 2009 H1N1 flu, in which returns became statistically significant when the window was extended to thirty days. Potentially, the prolonged effect of H1N1 reflects the behavior shown in media articles, in which a LexisNexis search of top world publications revealed elevated publicity over twenty days after the outbreak announcement. The animal diseases studied impacted livestock returns for the implicated commodity, while no noticeable changes occurred to the returns of the substitutable commodity. Although impacts were substantial for both commodities, the market response was greatest for nearby returns.

As for the variance, the contracts were statistically more sensitive to outbreaks. The first BSE case in the U.S. had the strongest and longest-lasting effect on volatility. Each disease contributed to adverse reactions in variance of returns following an outbreak, sometimes considerably changing the variance for the substitute commodity. The first BSE outbreak in the U.S. was the only food scare to increase the conditional variance in another market. Furthermore, all contracts experienced increased fluctuations following a food scare, regardless of maturity. Deferred contracts measured increased variance levels during the Canadian BSE case, thus showing that serious food scares have the possibility of harming international markets.

An important finding came from the spillover effects between the two markets. The lean hog variance decreased live cattle variance, indicating that uncertainty in one market stabilized fluctuations in a substitute commodity. This possibly stems from increased demand in cattle when pork supplies are variable. The greatest spillover effect is observed in deferred contracts, where the two commodities increased market instability in the other. Especially, live cattle variance significantly increased the variance of lean hog returns across all time horizons. The results give a more accurate measure of abnormal variance resulting from the outbreaks by incorporating a known variance inducing factor, such as spillover, into the conditional variance equation.

Implications

Mitigating food scares will minimize health and economic consequences resulting from outbreaks. Policymakers play a fundamental role in exacting the amount of responsibility for these disease outbreaks, making industries and companies liable for poor practices. Animal disease epidemics differ slightly in that the disease is contracted prior to processing. Public health officials and policymakers can, however, continue to regulate the types of ruminant feed, which have been the main source of animal disease.

Since preventing all animal health maladies remains an elusive target, government and industry can manage the economic effects by stabilizing an industry under financial distress. Producers, traders, and other market participants struggle to determine and maintain effective hedging positions when food scares plague commodity derivatives exchanges. Moreover, the situation becomes more detrimental when linkages between substitutable commodities elevate variance levels in commodities not directly implicated by the outbreak.

Further Research

There are other beef-related events, such as recalls, that may adversely impact returns and volatilities in futures markets. Including recall information may contribute to this analysis. Moreover, trade barriers were enacted and lifted during the years investigated. Further research adjusting for import and export policies following disease outbreaks could further clarify the exact economic costs associated with food scares.

REFERENCES

Andersen, T. G., & Bollerslev, T. (1998). “Answering the skeptics: yes, standard volatility models do provide accurate forecasts.” *International Economic Review,* 39(4):885-905.

Andersen, T. G., Diebold, F.X., Vega, C., & Bollerslev, T. (2003). “Micro effects of macro announcements: real-time price discovery in foreign exchange.” *American Economic Review*, 93:38-62.

Assefa, T., Meuwissen, M., & Lansink, A. G. (2015). “Food scares and price volatility: the case of German and Spanish pig chains.” In *2015 Conference, August 9-14, 2015, Milan, Italy* (No. 210966). *International Association of Agricultural Economists*.

Attavanich, W., McCarl, B. A., & Bessler, D. (2011). “The effect of H1N1 (swine flu) media coverage on agricultural commodity markets.” *Applied Economic Perspectives & Policy*, 33(2):241-259.

Binder, J. J. (1998). “The event study methodology since 1969.” *Review of Quantitative Finance and Accounting*, 11:111–37.

Brix, M. (2016). “Investigating beef market volatility. *Beef Research - Beef Issues Quarterly, March 2016.*” http://www.beefresearch.org/beefissuesquarterly.aspx?id=5669. [Accessed January 8, 2017]

Burton, M. & Young T. (1997). “Measuring meat consumers’ response to the perceived risks of BSE in Great Britain.” *Risk Decision and Policy,* 2(1):19-28.

Centers for Disease Control and Prevention (2015). BSE cases in North America, by year and country of death, 1993—February 2015. Available at: https://www.cdc.gov/prions/bse/bse-north-america.html.[Accessed October 30, 2016].

Colling, P. & Irwin, S. (1990). “The reaction of live hog futures prices to USDA hogs and pigs reports.” *American Journal of Agricultural Economics*, 72(1):84-94.

Grunewald, O., McNulty, M., & Biere, A. (1993). “Live cattle futures response to *cattle on feed* reports.” *American Journal of Agricultural Economics*, 75(1):131-137.

Hassouneh, I., Serra, T. & Gil, J. M. (2010). “Price transmission in the Spanish bovine sector: the BSE effect.” *American Journal of Agricultural Economics*, 41:33-42.

Isengildina-Massa, O., Karali, B., Irwin, S. H., Adjemian, M. K., and Cao, X. (2016). “The value of USDA information in a big data era.” *Proceedings of the NCCC-134 Conference on*

Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. [http://www.farmdoc.illinois.edu/nccc134].

Jin, Y. H., Power, G. J., & Elbakidze, L. (2008). "The impact of North American BSE events on live cattle futures prices." *American Journal of Agricultural Economics*, 90(5):1279-1286.

MacKinlay, A. C. (1997). "Event studies in economics and finance." *Journal of Economic Literature*, 35:13-39.

Marsh, T., Schroeder, T., & Mintert, J. (2004). "Impacts of meat product recalls on consumer demand in the USA." *Applied Economics*, 36:897-909.

Marsh, J., Brester, G., & Smith, V. (2008). "Effects of North American BSE events on U.S. cattle prices." *Review of Agricultural Economics*, 30(1):136-150.

Paiva, N. (2003). "The effects of mad cow disease on U.S. live cattle futures price". *Journal of Agricultural and Applied Economics*, 35(2):407-413.

Piggott, N., & Marsh, T. (2004). "Does food safety information impact U.S. meat demand?" *American Journal of Agricultural Economics*, 86(1): 154-174.

Pozo, V. F., & Schroeder, T. C. (2016). "Evaluating the costs of meat and poultry recalls to food firms using stock returns." *Food Policy*, 59:966-977.

Salin, V., & Hooker, N. H. (2001). "Stock market reaction to food recalls." *Review of Agricultural Economics*, 23(1): 33-46.

Schlenker, W., & Villas-Boas, S. B. (2009). "Consumer and market responses to mad cow disease." *American Journal of Agricultural Economics*, 91(4):1140-1152.

Serra, T. (2011). "Food scare crises and price volatility: The case of the BSE in Spain." *Food Policy*, 36:179-185.

Tse, Y., & Hackard, J. (2006). "Holy mad cow! Facts or (mis) perceptions: A clinical study." *Journal of Futures Markets*, 26(4):315-341.

Wang, Z., Salin, V., Hooker, N. H., & Leatham, D. (2002). "Stock market reaction to food recalls: a GARCH application." *Applied Economics Letters*, 9(15):979-987.