
HOLY MAD COW! FACTS OR (MIS)PERCEPTIONS: A CLINICAL STUDY

YIUMAN TSE*
JAMES C. HACKARD

The May 20, 2003, announcement confirming diagnosis in a Canadian cow of mad cow disease caused price disturbances in livestock, grain, and stock markets. Price and time data are used to provide a clinical study on the timing, persistency, and rationality of those disturbances in different U.S. markets, showing the three types of uncertainty that C. Avery and P. Zemsky (1998) use to identify herd behavior and the resulting mispricing. Markets react at different times, showing an informational cascading pattern. Misperceptions cause futures contract and stock reactions that are unsupported by the facts. Livestock and grain futures markets reactions suggest that people would replace beef with pork. Biogenetic stocks show price disturbances for companies with no relation to screening or treatment for mad cow disease. The market reactions to the December 23, 2003, announcement of the first incidence of mad cow disease in the United States are examined to see whether the markets have learned from the May event.
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*Correspondence author, College of Business, University of Texas at San Antonio, 501 West Durango Blvd, San Antonio, TX 78207; e-mail: yiuman.tse@utsa.edu

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- *Yiuman Tse is a Professor in the Department of Finance at the University of Texas in San Antonio, Texas.*
 - *James C. Hackard is an Assistant Professor in the Department of Economics and Finance at Southern Illinois University Edwardsville in Edwardsville, Illinois.*

INTRODUCTION

A basic precept of efficient market theory is that when new information enters the market it should be impounded in prices both quickly and accurately. It is much more difficult to assess market efficiency when an information shock appears to affect multiple securities and the effect on prices is lagged from one security to another. The question arises whether the progression of the price shocks in multiple securities is the result of cascading information or of herd behavior by traders. Herding behavior has been defined as “trade by an informed agent which follows the trends in past trades even though that trend is counter to his initial information about the asset value” (Avery & Zemsky, 1998).

The announcement of the diagnosis of mad cow disease in a Canadian cow was followed by such a progression of price shocks in U.S. livestock and grain futures market, and in certain segments of U.S. stock markets. Of interest are the responses to a series of news items on Tuesday, May 20, 2003, as evidence of the existence of herd behavior in the movement of prices in some securities in these markets. A May 21, 2003, story in the *Wall Street Journal* (WSJ) reported responses to the announcement of the discovery of mad cow disease in Canada. The story noted that talk of the diagnosis of mad cow disease in a single cow in Canada led live cattle and feeder cattle futures prices to fall by their daily limit in advance of the official announcement by the Canadian government. As reported in the WSJ article, the reading of the mad cow news by hog-market participants was that consumers would turn away from beef to other cuts of meat. In addition, hogs consume proportionally more soymeal as part of their feed rations than do cattle, leading grain traders to think that the news could mean greater domestic soymeal usage. This anticipated move toward more soymeal usage could also be attributed to a movement from bone meat meal to soymeal. Additional articles attribute the price and volume shocks in corn and wheat to the mad cow announcement. Several articles tied the mad cow announcement to price shocks in several segments of U.S. stock markets, specifically the stocks of corporations associated with hamburger and beef restaurants, beef and pork processing, and in biogenetic testing and treatment of meat products.

According to the WSJ article, Chicago Mercantile Exchange (CME) traders first heard a report of the discovery of bovine spongiform encephalopathy (BSE or mad cow disease) early the morning of May 20th from an industry newsletter, *Cattle Buyers Weekly*, in a news alert e-mailed to its subscribers at 11:10 A.M., Central Standard Time. This information was later confirmed by Canadian officials at a 12:15 P.M.

news conference. The officials stressed that only one animal was involved and it had not entered the food chain. They also pointed out that although no other cattle in the herd to which the diseased cow belonged had exhibited symptoms of mad cow disease, all cattle in the herd had been destroyed and tested, and were found to be free of the disease. As the initial effect of these stories deals with the livestock and grain futures markets in Chicago, the times reported in this article are all based on Central Standard Time (CST).

If the information on mad cow disease had affected only the prices of live cattle and feeder cattle futures, the adjustment of these prices would not be evidence of herd behavior. According to Avery and Zemsky (1998), when traders have private information on only a single dimension of uncertainty (the effect of a shock to the asset value), price adjustments prevent herd behavior. Herding arises when there are two dimensions of uncertainty (the existence and effect of a shock), but prices need not be distorted, as markets will discount the informativeness of trades during herding. It is the third dimension of uncertainty (the quality of traders' information) that can cause herd behavior to result in significant short-term mispricing.

The progression of price shocks occurring sequentially in other markets following the initial drop in cattle futures markets, particularly when those shocks seem to be misdirected and out of proportion to the facts underlying the characteristics of the securities, provides evidence of the other dimensions of uncertainty resulting from this event. This progression could also be a result of decay in price transmission from market to market. The severity of the shocks and the slowness of the rebound of the prices may be because the event occurred so close to the U.S. markets, thus adding uncertainty to the safety of the U.S. beef supply chain, and affecting investor behavior.

The effect of information in spillover in livestock and grain markets was noted in a market analysis by Professor Michael Haigh in a May 2003 issue of the *Maryland Grain and Livestock Report*, published weekly by the University of Maryland. Haigh noted that sometimes when there is little fundamental news, spillover pressure from other markets dominates price movement. In this article, these price responses are shown to be more consistent with herd behavior than with theoretically efficient market behavior.

The importance of mad cow disease in the fast food and restaurant markets of the United States stems from the fear that it will be transmitted to humans through the consumption of infected meat in hamburgers or steaks. Mad cow disease is a progressive neurological disorder of

cattle that can be transmitted to other species, including humans, through the consumption of the infected portion of a diseased animal.

To show that herd behavior exists in these markets, and that it led to significant mispricing, it must be established that the event (the mad cow announcement) produced uncertainty about the value of the futures contracts and stock prices in relation to their initial expected values, and that there is uncertainty surrounding the quality of traders' information relating the event and subsequent price movements. This is done by examining the timing, direction, and magnitude of price shocks in the selected securities. There is significance in the sense that, for several securities, prices move far more than is justified, and in some instances in the wrong direction.

The December 23, 2003 announcement by the U.S. Department of Agriculture (USDA) that a dairy cow in the state of Washington had been diagnosed with mad cow disease was met with similar reactions as those that followed the May 20th announcement. Because this recent announcement was made after markets had closed and it occurred during a period of holidays and early closures it is not possible to present a detailed comparison between the May and December announcements, but comparable price reactions for those data that are available are discussed here.

ARTICLE'S POSITION RELATIVE TO RELEVANT LITERATURE

There is a rich literature on the existence and effect of herd behavior in financial markets that is relevant to our discussion of the response of the markets to the series of information shocks that accompanied and followed the announcements of mad cow disease in Canada and the United States. Much early literature, while not identifying herd behavior as such, described the sequential arrival of information in the market and responses of investors that are identical to those described by Banerjee (1992). His definition of herd behavior is a sequential decision model in which each decision maker looks at the decisions made by previous decision makers in making his or her own decision. Similarly, Bikhchandani, Hirshleifer, and Welch (1992) describe the situation when the preponderance of one action chosen by earlier agents leads others to believe that the action is a good one as an "informational cascade."

Avery and Zemsky (1998) introduce the concept of three dimensions of uncertainty: value uncertainty, the effect of a shock to the asset value; event uncertainty, the existence of a shock; and composition

uncertainty, the uncertainty as to the average accuracy of traders' information. The authors show that with flexible prices, price adjustments prevent herd behavior when only the effect of the shock to asset value is uncertain. Avery and Zemsky state that when both the existence of a shock and its effect on asset value are uncertain, herding arises. They note that with informationally efficient prices, rational individuals only act based on information asymmetries between themselves and market makers, and that a history of trades can only be the source of this asymmetric information if it is interpreted differently by the market maker and informed traders. The cascading of information entering the market may cause informed traders to act, but the market maker may not recognize that an event has occurred and thus will not adjust prices, leading to herd behavior. Once the market maker learns about event uncertainty and allows prices to adjust, herding disappears.¹

While earlier studies conveyed the conditions under which herd behavior would occur, and the effect on prices of such behavior, it is the introduction of the third dimension of uncertainty by Avery and Zemsky (1998) that accounts for the context under which herd behavior leads to mispricing. This dimension, called *composition uncertainty*, arises when the market is uncertain *ex ante* about the proportion of informed and uninformed traders. This uncertainty makes it difficult for market participants to differentiate between trade imbalances caused by informed traders and those from uninformed traders engaged in herding behavior. This can lead to extreme short-run price effects due to herding.

Hong and Stein (1999) propose a model, namely of heterogeneity across investors, whereby investors observe different pieces of private information at different times. They discuss what they call "momentum trading," where momentum traders trade on information from earlier price movements without having full information on the relevance of those movements and where they are in the momentum cycle. Hong, Lim, and Stein (2000) test the Hong and Stein model and find that negative information diffuses gradually through the investing public—i.e., bad news travels slowly. This result is consistent with Bremer and Sweeny (1991) who imply in their conclusion that the market does not handle bad news efficiently.

While much of the previous literature focuses on herding behavior surrounding a single market, Cipriani and Guarino (2003) address herd behavior and contagion in financial markets using a theoretical model

¹In livestock and grain futures markets, there is no one designated market maker, rather undesignated market makers, scalpers, provide liquidity through active intraday trading. Scalpers play the role of the market maker in the Avery–Zemsky model.

with two assets that are jointly distributed and both traded in two markets. They argue that the fact that traders and market makers in one market are able to see the history of trades in another market can cause the price mechanism to fail in aggregating information. There is a contagious spillover when an information cascade starts in a market.

Other empirical studies take an event to show how people overreact to news in evaluating investments, or rely on misperceptions. For example, Huberman and Regev (2001) document how a May, 1998 *New York Times* article on the potential development of new cancer-curing drugs caused the shares of EntreMed to more than quadruple in price, even though the potential breakthrough had been reported 5 months earlier in a number of journals and newspapers (including the *Times*). This additional public attention, although not revealing any new information, caused a permanent rise in share prices, which also led to price increases in the shares of other biotechnology stocks. The EntreMed event discussed by Huberman and Regev relates the effects on a single stock and its market segment. Unlike previous empirical work, we emphasize the spillover effects among different markets (from livestock futures to grain futures and to the stock markets) showing that information is not disseminated efficiently, and that perceptions that are not always accurate form the basis for much of investment. This is consistent with the event uncertainty and composition uncertainty defined by Avery and Zemsky (1998).

Fair (2002) explains how daily intervals in stock price studies may cause one to miss the story behind movements and to incorrectly specify the event causing the changes. For that reason in this article the minute-by-minute prices of futures and stocks are tracked and related to the time when the information surrounding the mad cow diagnosis became public.

In the sections that follow, how the prices in the livestock futures market showed the effects of herd behavior following the announcements of mad cow disease diagnosis in Canada and the United States is examined as is how that herd behavior and its effects spilled over into the U.S. grain futures and stock markets, causing herd behavior and the attendant mispricing in those markets as well.

BACKGROUND ON MAD COW DISEASE AND THE EVENT

Bovine spongiform encephalopathy, a progressive neurological disorder of cattle is not contagious; it is not transmitted from one live cow to another live cow. It is transmitted from diseased cattle to healthy cattle through the inclusion of infected meat and bone meal processed from

the brain or spinal column from the carcass of a diseased cow in the diet of those healthy cattle. The causal agent of BSE is thought to be a mutant protein called prion. There is no known test for the disease in live cattle, and the symptoms may not show up in live cattle for many years after infection.

According to a 2001 U.S. Food and Drug Administration (FDA) background report on BSE, the disease was first identified in the United Kingdom in 1986, peaking in the United Kingdom in 1993 at almost 1,000 new cases per week. The United Kingdom has reported more than 183,000 total cases of BSE, with an additional 7,000 cases found in the European Union, Japan, and elsewhere. After the initial epidemic, aggressive actions in the United Kingdom to eradicate the disease caused the number of cases to fall sharply. However, there were 99 cases reported in France in 2000, following 31 cases in 1999. There were also cases reported in Germany, Spain, Denmark, and Italy for the first time in 2000. As of September 26, 2003, 190,885 of cases had been reported worldwide, with 97.7% of those in the United Kingdom. The rise in the number of reported cases may be partially the result of increased testing in those countries, or may reflect the long incubation period of cattle infected years ago during the time of the U.K. epidemic. The outbreaks in Britain, Continental Europe, and Japan caused sharp declines in beef consumption in those regions.

The United States, reacting to the epidemics in Europe, banned the use of mammalian bone and tissue meal as a protein supplement for cattle in 1997. On December 23, 2003, the USDA announced that a case of BSE had been diagnosed in a cow slaughtered in the state of Washington. It was confirmed by U.S. and Canadian officials on January 6, 2004 that this cow originated from a herd in Alberta and was born prior to the ban on the use of meat and bone meal as a feed supplement. Before the case in Washington, BSE had been kept out of this country by the combined efforts of the FDA, the USDA, the Centers for Disease Control and Prevention (CDC), and other federal agencies.

The related human disease is called variant Creutzfeldt-Jakob (vCJD), a rare but invariably fatal disease that can be contracted by eating meat from the brain or nervous system of a cow that is infected with BSE. Bovine spongiform encephalopathy and vCJD are members of the transmissible spongiform encephalopathies (TSEs). The most frightening aspects of vCJD are the long incubation period without detectable symptoms and the lack of a cure. As of December 1, 2003, 143 human cases of vCJD were reported in the United Kingdom, 6 cases in France, and 1 case each in Ireland, Italy, and the United States. The only case

reported in the United States was a woman in Florida diagnosed in April 2002. This woman was born in the United Kingdom in 1979 and had lived in the United States since 1992.

The only previous case of mad cow disease in Canada was discovered in 1993 in a bull that had been imported from the United Kingdom. Because the disease was found only in that single animal whose source could be isolated and there was not the public awareness of the connection between mad cow disease and vCJD, U.S. markets did not respond to the news in 1993. Since that incident there have been several events bringing the connection into the public consciousness. After the 1993 mad cow incident in Canada, the U.S. and Canadian governments have taken several steps to prevent the possible spread of the disease in cattle and humans. The steps taken by the USDA include prohibiting importation of live ruminant animals and most ruminant products from all of Europe.

However, what made the May 2003 event important was that this time the event struck close to home, the U.S. beef supply chain. This potential health risk and uncertainty over its implications from the incident may have influenced market behavior. Uncertainty regarding the sources of mad cow disease and vCJD, their treatment, and the ability of the United States to prevent their entry into the United States continue, is evidenced by a March 7, 2005, *Business Week* report, "Mad Cow's Stubborn Mystery."

The Canadian cow responsible for the current scare had been deemed unfit for human consumption because it was sickly and underweight when rendered on January 31, 2003. However, because the animal had been removed from the food chain, the sample was marked as nonurgent and set aside for testing by the provincial laboratory in Alberta. The sample was not tested until May 16, at which time a positive result was obtained and a portion of the sample was sent to an English lab for confirmation. While no other cattle in the herd of the infected cow had shown any symptoms of BSE, the entire herd was destroyed and 16 other herds were quarantined. However, Canadian officials have been unable to pinpoint the source of the infection. The fact that the process took so long and was not transparent to the market may have contributed to the severe reaction in U.S. markets.

DATA AND MARKET DESCRIPTION

The prices for cattle in cash markets in the U.S. respond to changes in futures prices within one trading day and futures markets are the center of price discovery for live cattle (Bessler & Covey, 1991). Transaction

data are not available in the cash market for livestock and meat products, but do exist for futures markets; therefore, the effect of the mad cow announcement on cattle and other futures is tracked here.

Futures transaction data of May 2003 from the CME and the Chicago Board of Trade (CBOT) are reported for livestock futures and grain futures, respectively. Daily open and settlement prices and volume are obtained from Commodity Systems, Inc. CME transaction data are publicly available from the Web site <http://www.cme.com/trading/dta> for 5 days after the day of trading. Among the data available are time, sales, and volume by tick files. The results are the same for both files, but the latter file was used for transaction volume data. There are a few studies using the volume by tick file. Hasbrouck (2004) uses these data to examine liquidity in the futures pits. Transaction volume data are not available from the CBOT. We collect data for the nearby contract of each commodity. The CME livestock futures include live cattle (June 2003 contract), feeder cattle (August contract), lean hogs (June contract), and pork bellies (July contract), and the CBOT grain futures (July 2003 contract) include soybeans, soybean meal, corn, and wheat.

Transaction stock data for the May event are taken from New York Stock Exchange (NYSE) Trade and Quote (TAQ) files. Daily stock data for the December event are downloaded from the Yahoo! Finance Web site. The S&P 500 Index Fund (SPY) is included as a proxy for the market to show that price movements are not market-related. Minute-by-minute data for futures and stocks is used, as the literature shows that use of daily data can mask the source of price movements. We collect price data at the end of each minute. News reports are taken from the Reuters News Service, as those reports are time stamped to minutes. News stories are also taken from CBS MarketWatch and Lexis/Nexis news service. Because the first public report of the diagnosis was the alert from *Cattle Buyers Weekly*, the editor, Steve Kay, was contacted directly to determine the time the report was circulated. He confirmed that he sent the message at 11:10 A.M.

Livestock futures are traded on the CME from 9:05 A.M. until 1:00 P.M. Grain futures trade on the CBOT from 9:30 A.M. until 1:15 P.M. Live cattle are those mature animals that are ready for slaughter and are soon to enter the food chain, so an announcement that calls into question the safety of beef should be reflected in the price of live cattle more quickly than the price of feeder cattle, which are immature cattle of insufficient weight to be eminently slaughtered. Lean hogs, like live cattle, are hogs of proper weight to be brought to market, and pork bellies are the cured, frozen byproducts of the slaughter of pigs, from which

bacon is produced. If a decrease in the demand for beef were perceived as causing an increase in the demand for pork, prices for lean hog and pork bellies futures would go up. This should also have an effect on the price of soybean and soymeal futures, as soymeal is the primary feed for poultry and hogs. Announcements affecting cattle and hogs also affect corn prices, as the greatest use for corn is as feed for livestock (primarily cattle). Wheat byproducts are also used in livestock feeds.

In the stock markets, McDonald's (Oak Brook, IL), Wendy's (Dublin, OH), Jack-in-the-Box (San Diego, CA), and Outback Steakhouse (Tampa, FL) are cited as the restaurants most at risk due to questions being raised about the safety of beef.² According to the 2002 Annual Report of McDonald's, it has only about a 2% exposure to Canada and its operations there are self-contained. John Glass, an analyst for Canadian Imperial Bank of Commerce's (CIBC) world markets who follows McDonald's, is quoted in Reuters news service on May 20th as saying Canada is relatively unimportant to McDonald's, but "this is a serious issue, because you're not dealing in facts, you're dealing in perception." It is interesting to note that at the 2003 Annual Meeting of McDonald's on May 22nd, shareholders were not concerned with the mad cow event, but were most concerned with McDonald's ability to improve food taste and service.

Other stocks that were cited as feeling the aftereffects of the Canadian announcement were food processors and companies involved in the testing and treatment of food-borne diseases. Tyson Foods, Inc. (Springdale, AZ) is the leading processor of beef in the United States and this position was reflected in the reaction of Tyson's stock prices to the announcement and subsequent price movements in cattle futures prices. Smithfield Foods (Smithfield, VA) is primarily a pork processor and hog producer. As pork is seen as a substitute for beef, the price of Smithfield Foods stock should react positively to the mad cow disease news.

SureBeam Corporation (San Diego, CA) is a provider of electronic irradiation systems and services for the food industry. A CBS MarketWatch report on May 20th discussed three other biogenetic stocks, Bio-Rad Laboratories, Inc. (Hercules, CA), V. I. Technologies, Inc. (Watertown, MA), and Paradigm Genetics, Inc. (Icoria, Inc., Research Triangle Park, NC). We directly contacted each of the biogenetic firms whose stock was affected to confirm whether the information contained in the news stories was accurate with regard to its

²One large burger chain, Burger King, is privately held.

involvement with mad cow disease. Bio-Rad is a multinational manufacturer and distributor of life science research products and clinical diagnostics products, and is the principal biotech firm doing research related to mad cow disease. According to its 2002 Annual Report, the company continues to be the leading provider of BSE tests to veterinary diagnostic laboratories. V.I. Technologies is a biotechnology firm that develops products related to the treatment of blood-borne diseases. Paradigm is a biotechnology company focusing on agricultural and health care issues, in particular crop traits, crop protection, green biotechnology, and predictive toxicology.

EMPIRICAL RESULTS

The historical relationship between prices in those markets with securities whose prices were affected by the mad cow announcement was examined to determine how those securities were related before the event. While daily returns of livestock futures were correlated with each other, and those of grain futures were correlated with each other, there appeared to be no significant correlation between livestock futures and grain futures, and the returns of neither futures market was correlated with the returns of the stocks in our study for the 10 years leading up to this study. Therefore, the reaction of the stocks was not a response to the change in the prices for the futures, but a result of the news surrounding the mad cow announcement.

May 20, 2003 Event

Table I shows closing prices for livestock futures, grain futures, and for the stocks included in our study for the 10-day period May 16th through May 29th, (Day -2 through Day $+7$). Opening prices are also shown for May 20th (Day 0) and May 21st (Day 1). Table II is a chronology of the events on May 20th surrounding the announcement of the mad cow disease.

Table III is a listing of the absolute minute-by-minute return statistics of the futures and stocks used in our study during the pre-event period—May 13th to May 19th (-5 to -1). The standard deviations of these absolute returns are used to determine the time when the futures or stocks first react to the mad cow news. For live cattle and feeder cattle futures, the times when the price changes reach their daily limit are considered the first reaction times. For all other futures and stocks, the times shown are those when there is a 2-minute period in which the changes in cumulative absolute returns on May 20th exceed 5 times

TABLE I
Daily Prices of Futures and Stocks: May 16–30, 2003

<i>Date: May</i>	<i>16th</i> <i>Fri</i>	<i>19th</i> <i>Mon</i>	<i>20th</i> <i>Tue</i>	<i>21st</i> <i>Wed</i>	<i>22nd</i> <i>Thu</i>	<i>23rd</i> <i>Fri</i>	<i>27th</i> <i>Tue</i>	<i>28th</i> <i>Wed</i>	<i>29th</i> <i>Thu</i>	<i>30th</i> <i>Fri</i>
<i>Day:</i>	<i>-2</i> <i>Close</i>	<i>-1</i> <i>Close</i>	<i>0</i> <i>Open</i>	<i>+1</i> <i>Open</i>	<i>+2</i> <i>Close</i>	<i>+3</i> <i>Close</i>	<i>+4</i> <i>Close</i>	<i>+5</i> <i>Close</i>	<i>+6</i> <i>Close</i>	<i>+7</i> <i>Close</i>
Livestock futures (cents per pound)										
Live cattle	74.05	73.90	73.70	71.05	72.90	73.15	74.37	75.25	75.55	75.57
Feeder cattle	84.67	84.47	84.20	81.67	83.90	83.77	85.12	85.62	85.45	85.30
Lean hog	66.87	67.05	66.85	65.90	65.12	64.40	63.07	64.07	64.22	64.85
Pork bellies	93.57	92.30	92.35	92.85	93.00	93.65	93.92	96.42	96.40	96.25
Grain futures (cents per bushel for soybeans, wheat, and corn; dollars per ton for soybean meal)										
Soybeans	642.0	637.0	637.0	642.0	640.0	638.0	624.0	630.0	621.4	631.0
Soybean meal	193.4	192.9	193.2	196.5	195.2	190.5	194.1	190.6	192.1	190.2
Wheat	338.4	328.4	327.0	333.4	332.2	325.4	327.4	319.0	324.0	324.2
Corn	254.2	246.6	248.0	246.4	245.4	243.6	242.0	241.2	245.0	244.2
Stocks (dollars per share)										
McDonald's	18.52	18.16	18.15	17.48	17.30	17.50	17.77	18.26	18.34	18.73
Wendy's	31.00	30.56	30.56	28.80	28.39	28.57	29.00	29.07	29.40	30.11
Jack-in-the-Box	20.95	20.68	20.70	20.40	19.94	19.89	20.17	20.69	20.95	21.02
Outback	37.10	36.62	36.70	35.25	35.24	36.03	36.30	36.85	36.90	36.95
Tyson Foods	9.10	9.47	9.48	9.01	9.00	8.90	9.31	9.26	9.20	9.50
Smithfield Foods	19.88	19.83	19.87	19.92	19.77	20.01	20.57	20.72	20.71	20.99
Bio-Rad Labs	50.00	48.85	48.85	54.96	56.70	58.75	57.82	59.31	58.25	59.00
SureBeam	2.79	2.96	2.99	3.20	2.90	2.83	2.81	2.90	3.03	3.20
V.I. Technologies	0.82	0.88	0.91	1.12	1.04	1.06	1.12	1.19	1.21	1.27
Paradigm Genetics	1.04	0.99	1.02	1.14	1.14	1.15	1.22	1.20	1.16	1.25
S&P 500 Index	94.87	92.65	92.82	92.11	92.65	93.57	95.40	95.67	95.42	96.95

Note. This table summarizes the daily prices for the period -2 to +7 from May 20, 2003, the day of the announcement confirming a diagnosis of mad cow disease in a Canadian cow, for the futures contracts and stocks affected by that announcement, and for the S&P 500 Index Fund (SPY).

TABLE II
Time of Events and Price Reactions on May 20, 2003

<i>Time (Central Standard Time)</i>	<i>Event</i>
11:10 A.M.	News alert from Steve Kay of <i>Cattle Buyers Weekly</i> : Bovine spongiform encephalopathy (BSE) comes to North America. Canada has its first case of BSE. The news that a beef cow in Alberta was discovered to have BSE will be confirmed shortly (11.15 MST) at a special news conference in Edmonton, Alta. CBW understands that an 8-year-old, native-born beef cow was discovered to be suffering from the brain-degenerative disease. One positive is that the cow was condemned and did not enter the food supply. CBW understands that all shipments of all types of Canadian cattle and beef to the United States are likely to be suspended after this morning's announcement.
11:52 A.M.	Canadian officials to brief on animal disease probe: Canadian agriculture officials, including Federal Agricultural Minister Lyle Vanclief, will hold a news briefing in Edmonton, Alberta, at 12:15 P.M. on "an animal disease investigation." Commodities markets said there were rumors that the authorities were poised to announce a case of mad cow disease in Canada, and that lifted some commodity prices. "There's talk on the floor there's mad cow in Canada . . . and they'll be banning bone meal on this. That's why soymeal is up," said one CBOT soy broker.
12:25 P.M.	Canada said on Tuesday it had found a case of mad cow disease in the western province of Alberta but stressed that the affected animal—the first mad cow case in a decade in Canada—had not entered the food chain.
12:41 P.M.	Reuters: US bans Canadian beef imports due to mad cow case. The US said it had temporarily banned Canadian beef imports.

the standard deviation of minute-by-minute absolute returns for the pre-event period. The sharp price changes shown in the following figures are consistent with the times determined using this criterion. The results are the same if we use 4 or 6 times of the standard deviation.

Figures 1 to 4 plot the minute-by-minute price and volume for live cattle, feeder cattle, lean hogs, and pork bellies futures, respectively, during the event week May 19th to May 23rd (Day -1 to Day $+3$). In Figure 1, the spike in volume and the drop in prices of live cattle early in the morning of May 20th are indicative of the time that the market reacts to the mad cow news. These movements occur prior to the news alert from *Cattle Buyers Weekly* and the subsequent official announcement, implying that the information was already available in the market.³

³While a Reuters report on May 20th stated that cattle prices had already been headed lower due to another health scare regarding the effect of a growth hormone used in the U.S. beef and veal industry, the drop to the daily limits was attributed to the mad cow announcement, according to analysts quoted in articles in the U.S. financial press, and confirmed directly by Steve Kay, editor of *Cattle Buyers Weekly*. Thus, the time at which those futures prices reached their daily limits was used as the time the cattle futures reacted to the mad cow announcement.

TABLE III
 Absolute Percentage Price Change: May 13–19, 2003
 (–5 to –1 Pre-Event Period)

	<i>Mean</i>	<i>SD</i>
Livestock futures		
Live cattle	0.0299	0.0361
Feeder cattle	0.0205	0.0356
Lean hog	0.0530	0.0613
Pork bellies	0.0607	0.0986
Grain futures		
Soybeans	0.0420	0.0491
Soybean meal	0.0507	0.0643
Wheat	0.0796	0.0410
Corn	0.0472	0.0801
Stocks		
McDonald's	0.0536	0.0581
Wendy's International	0.0299	0.0458
Jack-in-the-Box	0.0502	0.0922
Outback	0.0295	0.0458
Tyson Foods	0.0619	0.1103
Smithfield Foods	0.0613	0.1253
Bio-Rad Laboratories	0.0168	0.0019
SureBeam	0.1925	0.3336
V.I. Technologies	0.0843	0.5932
Paradigm Genetics	0.3183	1.3405
S&P 500 Index Fund (SPY)	0.0306	0.0275

Note. This table summarizes the absolute price movement for the five business days preceding the day of the announcement confirming the diagnosis of mad cow disease in a Canadian cow for the futures contracts and stocks affected by that announcement, and for the S&P 500 Index Fund (SPY).

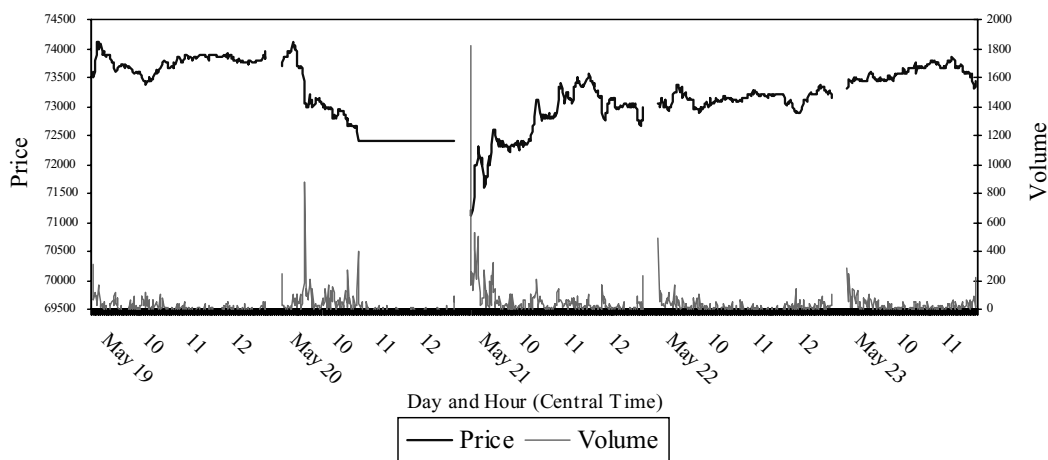


FIGURE 1
 Live cattle futures: price and volume—May 19–23, 2003.

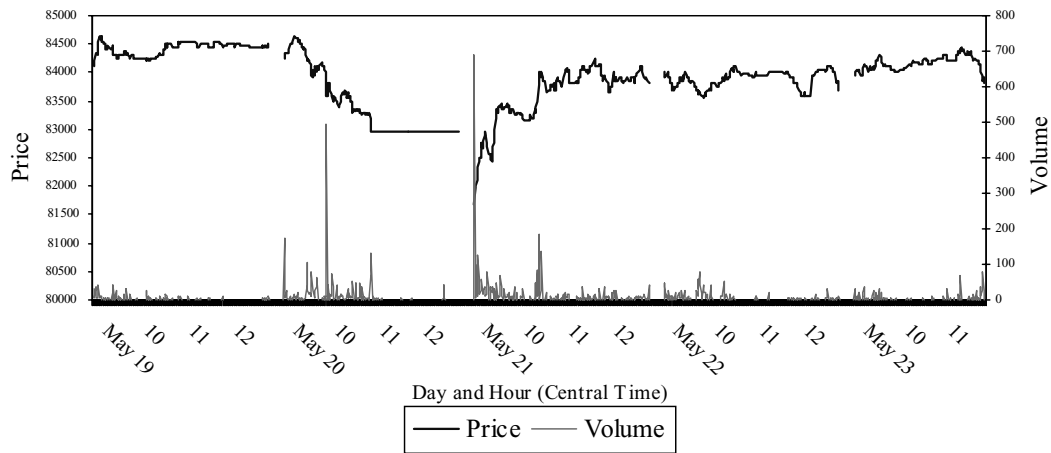


FIGURE 2
Feeder cattle futures: price and volume—May 19–23, 2003.

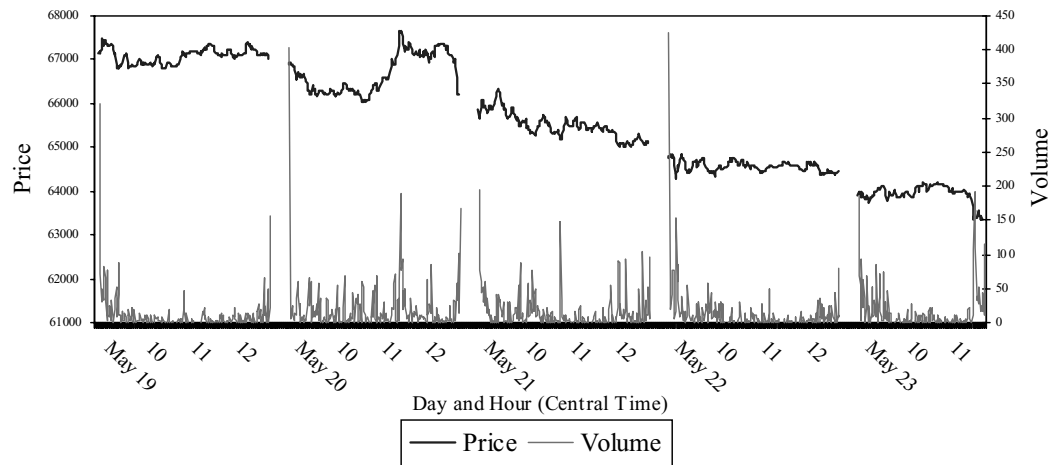


FIGURE 3
Lean hogs futures: price and volume—May 19–23, 2003.

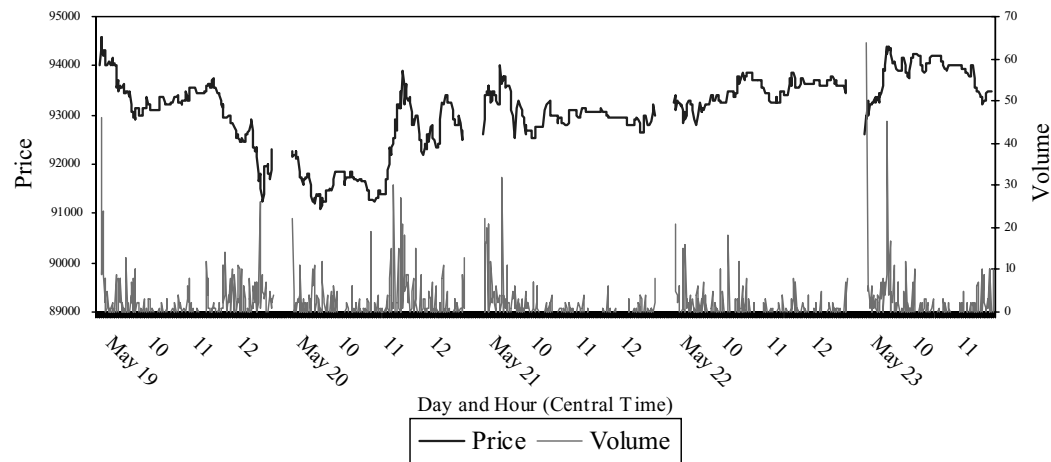


FIGURE 4
Pork bellies futures: price and volume—May 19–23, 2003.

The effect of the news causes live cattle futures prices to reach their daily limit of 72.40 cents per pound at 10:48 A.M. on May 20th, before the first Reuters news about the mad cow event at 11:52 A.M. and the Canadian official announcement at 12:15 P.M. The figure shows that trading virtually ceases at that time and that when trading resumes the next day, the opening price drops further to 71.05. Traders unwilling to trade at the limit price on May 20th reenter the market on May 21st, resulting in the spike in volume shown at the opening.⁴ Transaction volume data are not available for options on futures. However, it was noted that the daily volume for both futures and options on futures increased significantly on May 21st.⁵

The movement in live cattle futures prices over the next 3 days approaches preannouncement levels. Several Reuters news articles report that live cattle and feeder cattle futures recover over the rest of the week as traders realize that U.S. governmental protections against mad cow disease were put in place in 1997 and, more importantly, banning the import of Canadian beef should increase the demand for U.S. beef. However, this information is available from a Reuters report at 12:41 P.M. on May 20th and should be reflected at the opening of the market on May 21st. The fact that this information does not affect the prices in the short run is indicative of the uncertainty as to the accuracy or relevance of that information (the composition uncertainty of Avery and Zemsky, 1998). Prices continue to increase for the rest of May, ending up slightly higher than pre-event levels.

Figure 2 is a graph of the minute-by-minute price and volume for feeder cattle futures during the event week. The results are very similar to those shown for live cattle futures in Figure 1. On May 20th, the price decreases reach their daily limit at 11:02 A.M., 14 minutes after the nearby live cattle future prices drop to their daily limit. Again, this drop to the daily limit occurs before the announcement by Steve Kay of *Cattle Buyers Weekly*, indicating the presence of private information regarding the mad cow event by traders of feeder cattle futures.

Figure 3 shows the minute-by-minute pattern of price and volume movements for lean hog futures. Before the mad cow announcement, prices were sliding from their opening price on May 20th. Even though

⁴Price limits may also impose an unnecessary impediment to trading and prevent prices from efficiently reaching their equilibrium level. However, they also may reduce some of the adverse effects of herd behavior in highly volatile markets. See Kim and Rhee (1997) and references therein.

⁵The daily volumes for all the live cattle futures contracts traded on May 20th and 21st were 20,759 and 33,903 contracts, respectively, while for those same dates the volumes of calls (puts) on futures were 1,195 (480) and 1,938 (7,075) contracts, respectively.

price and volume spike upward at 11:17 A.M. and peak at 11:39 A.M., the market returns to its downward trend by the end of the trading day, closing at 66.20, 1.3% below its previous day's close. The initial market reaction reflected the effect of the announcement as an anticipated increase in demand for pork as a substitute for beef.

Figure 4 tracks the minute-by-minute price and volume for pork bellies futures. Like lean hog futures, the pork bellies futures price was on a downward path since the opening of the market on May 20th, and showed a significant increase in price and volume at 11:17 A.M., peaking at 11:39 A.M. The price closes at 92.82, up 0.5% from the previous close.

Using *cumulative* minute-by-minute returns on May 20th, we describe the pattern of price movements for the livestock futures in Figure 5, grain futures in Figure 6, restaurant stocks in Figure 7, biogenetic stocks in Figure 8, and food processor stocks in Figure 9. The first return is calculated as the log price change of the May 20th opening price from the May 19th closing price. Figure 5 demonstrates the lags among the four livestock futures in the absorption into prices of the news of mad cow diagnosis. The time frame of those lags is consistent with the hypothesis of informational cascade in the futures pits of the CME, which is one aspect of herd behavior.

Figure 6 shows that on May 20th the initial jumps in soybean and soymeal futures occur at 11:15 A.M. (2 minutes before that of lean hogs), reflecting the market perception that soymeal is a prime source of feed

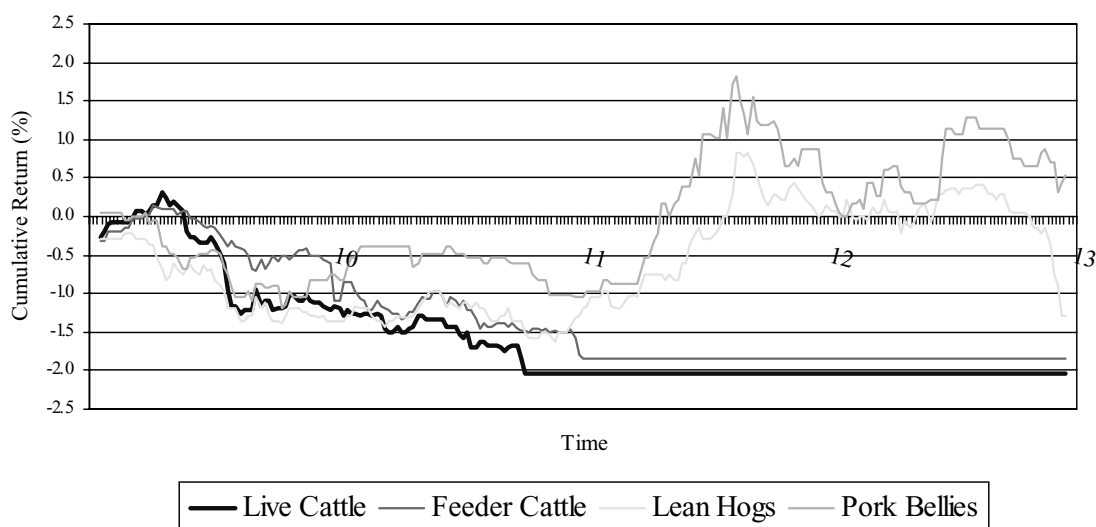


FIGURE 5
Livestock futures prices—May 20, 2003.

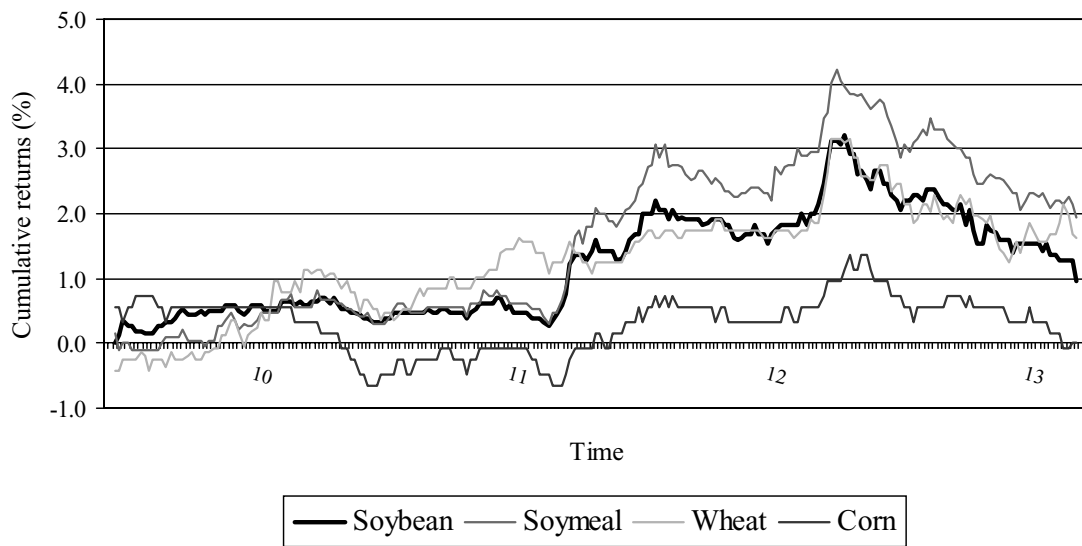


FIGURE 6
Grain futures prices—May 20, 2003.

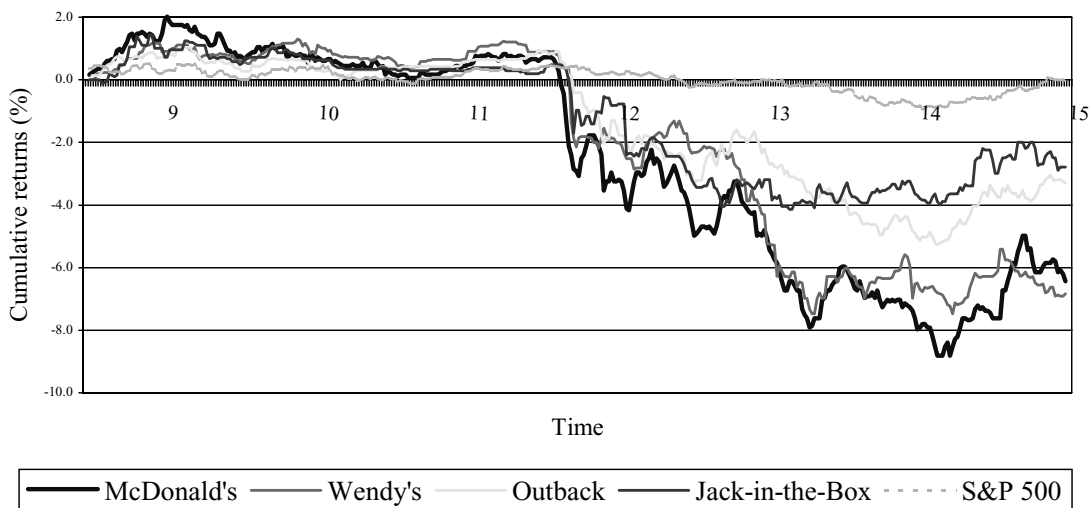


FIGURE 7
Restaurant stock prices—May 20, 2003.

for hogs.⁶ Corn and wheat futures react positively at 11:16 A.M. Soybean, soybean meal, and wheat surge at 12:15 P.M., the time at which the

⁶This reaction could also be attributable to the possibility expressed by a CBOT soy broker that the mad cow announcement could lead to the banning of feeding bone meal as a feed supplement. See the 11:52 A.M. news event listed in Table II. While the ban of bone meal as a feed supplement to cattle dated back to 1997, the feeding of bone meal to hogs and chickens and other nonruminants accounted for about 4.5% of processed high-protein feeds in 2002, according to the Economic Research Service, *Feed Situation and Outlook Yearbook*. The banning of bone meal as a supplement for hogs, combined with the fact that hogs already are a major consumer of soymeal, would lead informed traders to assume a jump in the demand for soymeal.

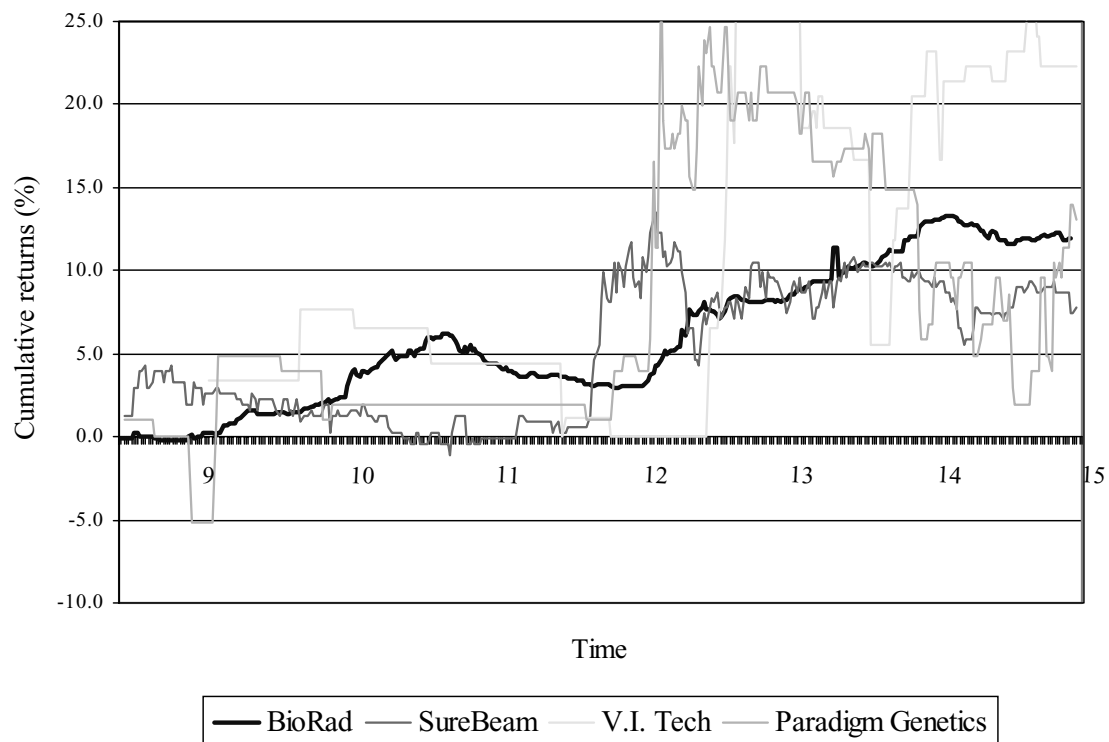


FIGURE 8
Biogenetic stock prices—May 20, 2003.

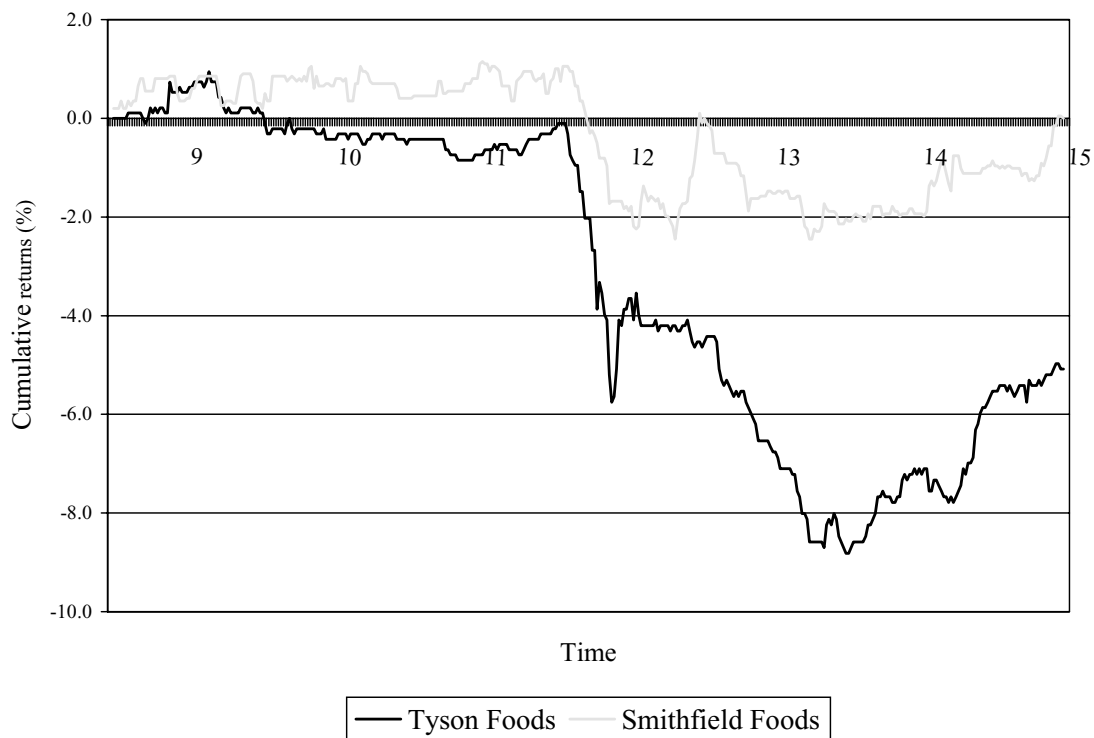


FIGURE 9
Food processor stock prices—May 20, 2003.

Canadian official announces the mad cow disease, while corn follows the surge 1 minute later. After reaching their peaks, all grain futures prices retreat. Soymeal and wheat futures increase about 2% for the day and soybean futures about 1%, while corn finishes at the same price as the previous close.

What is not rational about the response of corn prices is that it follows the price increases of soybean and soymeal. As the CBOT *Closing Grain Market Report* on May 20, 2003 describes, the mad cow disease

. . . sent soybean and soymeal futures soaring to new contract highs near midday. The bullish euphoria spread across the trading floor to send wheat rocketing and eventually sparking sympathetic gains in corn. However, the enthusiasm soon faded as market participants quickly digested the news and saw no real fundamental impact on corn with prices reversing direction to retrace the short-lived advances . . .

This is indicative of herd behavior on the part of corn futures traders being dragged along by the momentum of the other grain futures.

Figure 7 shows the price movements for the restaurant stocks of McDonald's, Wendy's, Outback Steakhouse, Jack-in-the-Box, and S&P 500 Index Fund (SPY) on May 20th. We include the SPY to show that overall market movement (fairly stable on that day) does not drive the results.⁷ The movement of BBH (not shown in the figure), a biotech exchange-traded fund, is similar to that of SPY. The figure indicates that McDonald's reacts at 11:37 A.M., followed by Wendy's and Jack-in-the-Box at 11:42 A.M., and Outback at 11:43 A.M. This is consistent with the notion that McDonald's is more closely followed by financial analysts and investors.

The lag between livestock futures, grain futures, and stock price movements indicates a spillover effect from the futures market to the stock market, which is consistent with cascading information and herd behavior, as defined in the relevant literature. However, when comparing futures and stocks, we are moving across exchanges which could result in additional time lags. This could be a result of decay in price transmission as information from the initial livestock futures price shock is reflected in those other markets.

Figure 8 shows the price pattern for the biogenetic stocks of SureBeam, BioRad Laboratories, V.I. Technologies, and Paradigm

⁷There is an announcement of an elevation of the terror alert status at mid-afternoon, and the effect of that announcement is evidenced by a slight dip in the SPY prices. However, that dip occurs much later than the reactions shown for the mad cow announcement.

Genetics on May 20th. It shows that SureBeam is the first to react, with a jump of 10% above its previous closing price at the interval of 11:41 to 11:45 A.M., closing the day up 6.8%. Paradigm is next to react, with a price jump of 10% at 12:06 P.M. V.I. Technologies' price spikes over 20% at 12:29 P.M. and continues to fluctuate throughout the day, closing with a 24.1% return. Paradigm retreats from its high to end the day at 14.1%. SureBeam fluctuates between +5% and +10%, closing at 7.8%. Bio-Rad provides a fairly steady rise for the day to 11.7%.

Following the increase in prices for these three stocks, a report entitled "Three Companies Jump on Canadian 'Mad Cow' Case" appeared on CBS Market Watch, at 1:40 P.M. on May 20th. The story incorrectly reported the status of work that had been done by Paradigm in developing tests for detecting mad cow disease. At 3:37 P.M. on May 21st, CBS Market Watch corrected the information it had previously reported for Paradigm, stating that the company had worked on such a project in 2000 and 2001, but was not currently doing so. Paradigm stock still closed the month with an increase of over 20% from its closing on May 19th. This failure to return to the preannouncement price after the story corrected the initial information is consistent with herd behavior when traders are unsure of the quality of the information they are receiving and fail to incorporate new information into prices.

If the market correctly interprets the information, SureBeam, Paradigm, and V.I. Technologies prices should not change, because these three biogenetic stocks are not currently engaged in research or testing for mad cow disease. Only Bio-Rad looks to profit from an increase in testing for mad cow disease. In particular, SureBeam does not provide testing services for mad cow disease, and its irradiation treatment for food does not affect the miniscule prion protein responsible for BSE and vCJD, so the market incorrectly imputes a benefit to SureBeam from the mad cow scare. The company Web site of SureBeam contains a response to frequently asked questions (FAQ) stating that its processes are not used to treat meat for mad cow disease.⁸ The occurrence of these initial reactions and the time it takes for the market to recognize the true relationship (or lack thereof) between the mad cow announcement and the information that should have affected prices is consistent with the notion of event uncertainty, value uncertainty, and composition

⁸The FAQ is "Can SureBeam be used for BSE (Mad Cow Disease) or Foot & Mouth Disease?", and the answer is "No." A company spokesman of SureBeam confirmed to us that the FAQ response was posted on the Web site prior to May 20, 2003.

uncertainty that Avery and Zemsky (1998) cite as the conditions for mispricing under herd behavior.

Figure 9 describes the price movement for the food processors, Tyson Foods and Smithfield Foods, on May 20th. The initial drop of almost 6% in the Tyson stock price is consistent with the fact that Tyson is the leading processor of beef in the United States and has a slaughterhouse in the affected Canadian province. However, that drop occurs at 11:37 A.M. (the same time that McDonald's drops), more than half an hour after the mad cow news was impounded in beef futures prices, consistent with the premise of cascading information in securities markets. Tyson prices continue their decline, reaching a daily low of about 8.8% below previous closing price at just after 1:30 P.M., and rebounding only slightly to close at negative 5%.

Smithfield reacts to the news and drops at 11:39 A.M., 2 minutes after Tyson's reaction. If the market correctly realizes that Smithfield is the leading processor of pork products, then the reaction of Smithfield should follow that of pork futures, and exhibit increases in price just as pork futures do. Instead, it appears that Smithfield simply follows the reaction of Tyson. Smithfield does rebound after its initial drop of about 2% and eventually returns almost to its previous closing price, but the uncertainty of the value of Smithfield stock and its slowness in rebounding from its reaction to the mad cow announcement is consistent with the value uncertainty and composition uncertainty of herd behavior.⁹

The overall results show that reactions to mad-cow-related information enter the markets with varying time lags, and are coupled with inaccurate assessments of the effects of that information on the values of the futures contracts and stocks. The lagged pattern of responses by futures and stock prices in our study is consistent with the findings in Hong, Lim and Stein (2000) and Bremer and Sweeny (1991) that the market does not handle bad news efficiently, as are the implicit misperceptions found in price movements that are at odds with the nature of the underlying firms and securities, indicating event and composition uncertainty.

December 23, 2003 Event: Do the Markets Learn From the May Event?

The December 23, 2003 announcement of a mad cow diagnosis in Washington State triggers responses similar to those following the May 20th event. The first mention of the December announcement is in a

⁹Pork processors may be constrained by the "stickiness" of retail prices or countervailing market power of retail chains, and thus Smithfield may not be able to raise prices, leading to a reduction in their operating margin and a decline in short-term returns from pork processing.

Reuters news story at 4:33 P.M. Chicago time that day.¹⁰ Because the announcement was made after the close of the markets, it is not possible to track the minute-by-minute reactions as was done for the earlier event.¹¹ All of the markets closed early on the afternoons of December 24th and 26th and were closed all day on December 25th. However, the daily price movements of nearby futures contracts and stocks can be examined to see if the markets learned anything from the May event.

As expected, live cattle futures open (and close) December 24th at 90.62, which is at the daily limit of 1.50 cents per pound lower than the December 23rd close. Details that became available during the day on December 24th cause live cattle futures to open and close on December 26th at the daily limit of 3.00 cents lower per pound (87.62), followed by two consecutive days when the opening and closing prices reflect the 5.00 cent daily limits, at 82.62 and 77.62 on December 29 and 30, respectively. As more news that is positive enters the market, showing that U.S. consumers have little to fear from the event, the downward spiral of prices for live cattle futures slows. The net effect is a decline in live cattle futures of 18% from December 23, 2003 through January 5, 2004 (Day +7). Feeder cattle futures prices follow the same pattern as live cattle futures, and the net effect is a 13% drop for the period.

The fact that cattle futures prices continue to slide after the December event, while they rebounded to pre-event levels within 4 trading days of the May event, is undoubtedly due to the May discovery being in Canada while the December event is in the United States. Once it was determined that the cow from the Washington herd was born in Canada prior to the ban on meat and bone meal feed, beef prices begin to rebound. However, the ban on U.S. beef by Japan and other countries continue to keep futures prices lower than they were before the announcement in Washington.

Inexplicably, lean hog futures prices drop by 3.5% (from 53.07 to 51.20) and pork bellies futures drop by 2.7% (from 85.72 to 83.40) on December 24th. This is different from the initial reaction that occurred in May and with the presumption that consumers would flee from beef to pork. Several news sources were searched for other information shocks that might have impacted these prices during this period; there were none. Thus, it was concluded that the mad cow announcement was the event that caused the price shocks. However, both rebound on

¹⁰The official announcement by the USDA is at 4:30 P.M. Federal regulators have investigated whether some futures traders had advance knowledge before the announcement.

¹¹The editor of *Cattle Buyers Weekly* informed us that the first e-mail that he sent to subscribers regarding this mad cow disease was on the afternoon of December 24 (Kay, 2003).

December 26th and after. Lean hog futures end January 5 up about 5% from their December 23rd close; pork bellies futures up 1%.

Just as in the May study period, soybean and soymeal futures prices respond positively to the mad cow announcement, rising 2.5% and 4.5% respectively, on December 24th. Both follow with a second day of strong advances, of 4.3% and 5.7% respectively, on December 26th. Corn and wheat futures prices initially react negatively to the mad cow news, dropping 3.3% and 2% respectively, on December 24th. Analysts attribute this drop to the carryover of the drop in the market for beef, for which corn is the primary feed. However, after the initial drop in prices, both corn and wheat rebound, with corn finishing January 5th up 3.8% from its December 23rd close and wheat up 7.5% for the same period. It is hard to reconcile this pattern with the continued decline in beef futures prices, and may reflect the momentum effect of the other grain futures. Soybean futures finish January 5th up 7.5% above its December 23rd close and soymeal futures are up 8.4% for the same period.

In the stock markets, the restaurant stocks, McDonald's, Wendy's, Jack-in-the-Box, and Outback Steakhouse, all suffer initial drops of about 5% in their stock prices on December 24th. According to CBS MarketWatch, Tyson Foods initially benefited by the announcement and its price jumped 4% in after-hours trading due to the expectation that Americans would switch from beef to poultry; Tyson is perceived mainly as a poultry processor. This shows how misperceptions can enter the market. In fact, once the markets open on December 24th, Tyson's stock price falls to finish the day down about 8% in response to the knowledge that Tyson is also the leading processor of beef. Tyson's stock continues its decline for one more day before having a brief rebound to end January 5 down about 7% from its December 23rd close. The price of stock for Smithfield Foods declines throughout the postevent period, ending at 8% below its preannouncement closing price, a result that is not consistent with the knowledge that Smithfield is primarily a pork producer and processor.

All four biogenetic stocks surge on December 24th: SureBeam 4.9%, Paradigm Genetics 8.5%, V. I. Technologies 37.3%, and Bio-Rad 18.4%. However, as discussed for the May event, only Bio-Rad is directly involved in mad cow testing. A story reported in Reuters on that day noted that V.I. Technologies, in particular, has run into significant problems and delays with the development of its experimental human blood-cleaning system. SureBeam is not involved in the treatment of beef for mad cow disease, and Paradigm is not engaged in research and testing for the disease. Therefore, any increases in their stock prices that are reactions to the mad cow announcement would be due to the

misperception of the market. However, it is worth mentioning that SureBeam was delisted from NASDAQ (National Association of Security Dealers Automated Quotation System) in November 2003 and is now listed only on the Pink Sheets with a trading price less than \$1.

CONCLUSIONS

The May 20, 2003 announcement confirming a single case of mad cow disease in Canada rattled different sectors of the U.S. markets. It was found that related livestock and grain futures and stock prices do not quickly and accurately process information, but follow a pattern of herd behavior. This behavior is evidenced by the uncertainty about the impact of the announcement on the value of certain securities, and the composition of information entering the markets immediately following the initial announcement. These uncertainties are the aspects of herd behavior that Avery and Zemsky (1998) cite as the conditions necessary for herd behavior to lead to mispricing. There is also a lagged pattern of responses by futures and stock prices in this study that is consistent with the findings in Hong, Lim and Stein (2000) and Bremer and Sweeny (1991) that the market does not handle bad news efficiently, as are the implicit misperceptions found in price movements that are at odds with the nature of the underlying firms and securities, indicating event and composition uncertainty.

Prior to the official announcement in Canada at 12:15 P.M. and at 11:10 A.M. e-mail alert to subscribers of *Cattle Buyers Weekly*, prices of CME live cattle and feeder cattle futures had already tumbled to their daily price limits. Although the U.S. ban on importing Canadian beef was announced only half an hour after the official announcement on the same day, it took the rest of the week for live cattle and feeder cattle futures to recover as traders realized that the ban would increase the demand for U.S. beef. This slow reaction to additional news that should have mitigated the mad cow announcement may be related to the uncertainty that traders face about how consumers might respond to the mad cow event.

Other livestock futures and the CBOT soybean, soybean meal, corn, and wheat futures reacted within 2 minutes. However, this was more than 20 minutes after live cattle futures had already reached their daily limit. At 12:15 P.M., the prices of grain futures rose. Adverse information about beef should not have affected each of the grains in the same way. Soybean meal is used as the primary feed for hogs. The misperceived increase in demand for pork as a substitute for beef could and did cause an increase in the prices for soybean and soymeal futures, which may

have been exacerbated by the perception that the ban on bone meal as a feed supplement for cattle would be extended to hogs, leading to an even higher demand for soymeal. But corn is a primary source of feed for both cattle and hogs, so corn futures should not have followed the price increase of soybean and soybean meal futures.

In the stock market, McDonald's showed a drop in prices at 11:37 A.M. The prices of Wendy's, Inc., Jack-in-the-Box, and Outback Steakhouse followed the drop about 5 minutes later. If the mad cow announcement was truly relevant for these restaurant chains, they should all have reacted at the same time. Furthermore, the plunge for McDonald's stock was 50 minutes after the price of live cattle futures fell to its daily limit. This cascading of price movements is consistent with the premise that adverse information moves slowly through the markets.

Tyson Foods is the leading processor of beef, and news viewed as adverse for the demand for beef should also have been bad news for its stock. However, the other food processing company, Smithfield Foods, is primarily a pork processor; it should have received a boost from the perceived demand for pork, not a decrease in its stock price. Four biogenetic firms, SureBeam, Paradigm Genetics, Bio-Rad Laboratories, and V.I. Technologies, showed a significant and positive reaction to the mad cow announcement. Of these, only Bio-Rad Labs is currently engaged in mad cow testing and research.

This clinical study finds that the reactions of these different markets follow the momentum of other traders in stocks they perceive to be similar. An important finding is that the effects of the mad cow announcement cascade from the livestock futures market to the grain futures market and finally to the equities market. Previous literature concentrates on the effect of adverse information on the behavior of individual stocks, or between stocks within a single market.

The December 23, 2003 announcement of the diagnosis of BSE in a cow slaughtered in Washington State gives an opportunity to examine whether the markets have learned from the experience of the May 20, 2003 announcement. However, the December announcement occurred when all markets were closed; therefore, it is not possible to examine the time lags among different markets. Moreover, the December event is likely to draw more attention from the U.S. public. There are some inconsistencies in the markets, however, that are similar to those following the May announcement, particularly among food processor and biogenetic stocks, which provide additional evidence of herd behavior.

The psychology of traders that causes them to engage in herd behavior is not examined here, nor is why bad news is less quickly incorporated

into the markets than good news. Working in multiple interconnected markets that are filled with uncertainty, short-run behavior does not always reflect the true nature of the information that enters those markets. While the finding of herd behavior in these events is informative, there remains a need for further study and documentation to show how markets behave in extreme situations, to identify more carefully important market linkages, and to assess the source of behavior and implications for performance.

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