THREE ESSAYS CONCERNING ECONOMIC ANALYSIS ASSOCIATED WITH THE SUPPLY CHAIN

A Dissertation

by

PABLO SHERWELL CABELLO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2006

Major Subject: Agricultural Economics

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Approved by:

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ABSTRACT

Three Essays Concerning Economic Analysis Associated with the Supply Chain.

(August 2006)

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Analyzing different aspects of the supply chain aids in understanding how firms behave, interact and respond within an industry. Some concepts used to carry out this analysis include asymmetric price transmission, event study methodology and event costing analysis. Each of these topics is discussed in this dissertation, presented as a set of three separate papers.

The first paper analyzes asymmetric price transmission and elasticities of price transmission at the farm-retail level for whole and two percent milk in selected cities in the United States. The theoretical core of this paper relies on a comparison between the traditional Houck approach and the error correction model proposed by von Cramon-Taubadel and Fahlbusch. We reject the null hypothesis of symmetry for each product and city under both approaches. We also find little evidence of statistical superiority between the classic Houck approach and the error correction model.

The second paper uses financial market event study methodology to calculate the economic impact on the supply chain related to one of the worst disease outbreaks in the food industry in the United States. This event began on November 3, 2003, when the

Associated Press reported a hepatitis advisory in the Beaver Valley, Pennsylvania. This outbreak directly involved two publicly traded companies: Prandium and Sysco. The market model is used as the main foundation of the economic analysis. There is no evidence of abnormal rates of return or spillover effects in relation to the outbreak. However, there is evidence that volatility of returns increases after the event.

The third paper develops a general conceptual economic module to quantify the impact of an animal disease outbreak. This study develops a generic economic module, which estimates cost in the face of a simulated animal disease outbreak under different mitigation strategies. This model was subsequently applied in a case study: a hypothetical case of a foot-and-mouth (FMD) outbreak in the Texas Panhandle analyzed under five different ex-post mitigation strategies. The results show that the most effective strategy is to slaughter and not to vaccinate.

We conclude that analyzing the supply chain is important in understanding how markets behave.

To
Luis
Connie
Juan
Emmnuel
Ricardo
and Santiago

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CHAPTER I

INTRODUCTION

International and domestic market integration has brought many opportunities to businesses and consumers. Today, small, medium and large firms have the advantage of operating in different markets, allowing them to minimize their costs and maximize their profits through better integration in the supply chain. By definition, supply chain is the set of autonomous or semi-autonomous businesses collectively responsible to produce, manufacture and distribution of one or more related products, Jayashankar et al (1995).

Today, many firms depend on a high level of integration in regional, national and international markets in order to reach economies of scale, compete and grow. However, this market integration makes supply chain analysis more complex. The higher the dynamics and players in the supply chain, the higher the complexity to analyze it. For example, agricultural firms are integrated, both vertically and horizontally, in many domestic and international markets. Thus it is important to understand how local farms react to international markets. For instance, the transmission of prices from one market to another is one important pattern that economists study.

Price transmission analysis aids in understanding how markets are integrated at different levels, i.e. regional, national or international. Moreover, this type of analysis allows economists to explore how economic agents, such as producer and retailers, interact among themselves.

This dissertation follows the style of *American Economic Review*.

Knowing how prices flow along the supply chain is important for price determination and price reaction at a firm level. Moreover, price transmission analysis aims to determine the level of market efficiency. If prices are rigid, that is, not channeled fully between agents, there could be concentration of the markets, high transaction costs or there might be some governmental policies that are preventing the markets from operating efficiently. For example, if prices do not transmit fully, i.e. from a producer to a distributor, the market may be concentrated due to the power that one agent may have over another.

Most of the empirical studies that test for the presence of asymmetric price transmission have been based on a variable-splitting technique developed by Wolffram (1971) and later adapted by Houck (1977) and Ward (1982). This technique, conventionally called the Houck approach, has been employed in the agricultural economics literature in considering asymmetric price transmission.

However, since prices tend to be cointegrated, Von Cramon-Taubadel and Fahlbusch (1994) demonstrated that an asymmetric error correction model (ECM) based on the work of Granger and Lee (1989) could be more appropriate to test for asymmetric price transmission. Von Cramon-Taubadel and Loy (1999) extended this application of the asymmetric ECM and concluded that this method was more appropriate than the use of the conventional Houck.

A natural extension of the price transmission analysis is the calculation of the elasticities of price transmission (EPT), which has not received much covered in the literature. EPT's measure the percentage change in retail price of a commodity due to a one percent change in farm price. Segmenting the elasticity of price transmission will capture the positive and negative changes separately, avoiding the typical assumption that the elasticities of price transmission are the same weather farm prices rise or fall. The segmentation provides vital information about the relationship between the prices of two economic agents, i.e. farmer and retailer.

Another important issue regarding the supply chain is how firms respond to unexpected events. For instance, agricultural and food firms tend to be highly integrated. With this integration and the sensitive degree of product management, safety becomes an important issue to be studied. A disease outbreak, for example, can generate high losses not only to the main party involved but also may affect other firms positioned in the same supply chain.

Event study methodology aids investigation of how a particular event, such as a disease outbreak, affects the value of the firm as measured by stock market valuation. In addition, this methodology can be augmented to explore how these effects may be channeled to other firms along the supply chain. The application of the simple market model has been the conventional tool for economists to perform event studies.

The market model utilizes the financial markets rationale, which states that the return and risk of a firm's security are a function of the company's performance relative to the market. Thus an unexpected event, such as a disease outbreak, may affect the stock of the firm and the ones linked to it along the supply chain.

Following the analysis of unexpected events, it is appropriate to compute not only the impact but also to analyze economically the cost of different control options to mitigate an unexpected event. As mentioned, due to the high integration of agricultural markets and its importance to regional and national food businesses, a disease outbreak, for instance, will have disastrous consequences.

Thus, applied economists must be trained to be able to interact with other scientists, such as veterinarians and epidemiologists, to incorporate into their studies into economic models that quantify the magnitudes of disease outbreaks and control strategies among them. In additions, an economist must be able to generate different scenarios under different circumstances, so policy makers can make better decisions.

The main objective of this dissertation is to address three important issues related to the supply chain: price transmission, the use of event study to analyze the economic impact of unexpected episodes and the spillovers in the industry and, finally, the development of a general conceptual economic model to analyze the impact of a disease along with the evaluation of different control options to mitigate a disease outbreak.

This dissertation consists of three papers. The first paper (Chapter II) addresses the importance of testing for asymmetric price transmission. The conventional Houck approach is used and is extended to capture for time series cointegration. Then, the results are compared under the proposed von Cramon-Taubadel and Loy error correction model (ECM) approach. Moreover, the short- and long-run elasticities of price transmission between the farm and retail levels of the marketing channel for whole milk and two percent milk for seven US cities are calculated. Monthly data over the period from January 1994 to October 2002 are used.

The second paper (Chapter III) uses the event study methodology to explore how one of the worst food disease outbreaks in the United States affected the main actors involved. The simple market model is used to perform the event study. In addition, this model is augmented in order to explore spillovers along the supply chain, as well as to check for volatility impacts.

The third paper (Chapter IV) develops a general economic module that estimates the costs of a disease outbreak at the beginning of a supply chain. Also, this model compares quantitatively different control options to mitigate the disease. Then, this model uses a case study to analyze a hypothetical foot-and-mouth disease outbreak in the area of Panhandle, Texas. Finally, Chapter V summarizes the results of this dissertation and renders concluding remarks.

CHAPTER II

SPATIAL ASYMMETRY IN FARM-RETAIL PRICE TRANSMISSION ASSOCIATED WITH FLUID MILK PRODUCTS

2.1 BACKGROUND

Testing for asymmetric price transmission and calculating elasticities of price transmission are of great importance in applied economics. The relationship between farm and retail prices provides insights into marketing efficiency as well as consumer and producer welfare. Farm to retail price transmission elasticities are defined as the percentage change in the retail price of a product due to a one percent change in the corresponding farm price. As Aguiar and Santana (2002) pointed out, most empirical estimates of elasticities of price transmission have been obtained assuming symmetric price transmission, meaning that retail prices would respond in the same manner for both increases and decreases in farm prices. However, the literature is replete with evidence to indicate that asymmetric price transmission is very common. To illustrate, Peltzman (2000) found evidence of asymmetric price transmission in over two-thirds of his sample of hundred producer and consumer goods in the United States.

Kinnucan and Forker (1987), Hahn (1990), and Bernard and Willett (1996) found that retail prices were more sensitive to increases in farm prices than to decreases in farm prices. Ward (1982) and Punyawadee, Boyd, and Faminow (1991), on the other hand, found that retail prices were more sensitive to decreases in farm prices than to increases in farm prices. Lass, Mawunyo and Goefrey (2001) found asymmetric speed of price adjustment for fluid milk for Boston and Hartford during the operation of the Northeast Compact. Outside of agriculture, Borenstein, Cameron and Gilbert (1997) found that gasoline prices were more responsive to increases in oil prices than to decreases in oil prices.

Importantly, while much of the empirical focus has been on methods to detect asymmetric price transmission, few analysts have actually computed the resulting elasticities of price transmission. This omission is curious because the computation of elasticities of price transmission is a natural by-product of the empirical analyses.

Over the last three decades, most empirical efforts to test for the presence of asymmetric price transmission have been based on a variable-splitting technique developed by Wolffram (1971) and later adapted by Houck (1977) and Ward (1982). This technique has been employed in the agricultural economics literature in considering asymmetric price transmission. Examples include the examination of price asymmetry in spatial fed cattle markets by Bailey and Borsen (1989); price asymmetry in the US pork marketing channel by Boyd and Brorsen (1988) and Miller and Hayenga (2001) and in the Alberta pork market by Punyawadee, Boyd, and Faminow (1991); asymmetry in farm-retail price transmission in the dairy sector by Kinnucan and Forker (1987); price asymmetry in the international wheat market by Mohanty, Peterson, and Kruse (1995); price asymmetry in peanut butter by Zhang, Fletcher, and Carley (1995); asymmetric price relationships in the US broiler industry by Bernard and Willett (1996); price transmission asymmetry in pork and beef markets by Hahn (1990); asymmetry in shipping point, wholesale and retail markets for red delicious apples by Willett, Hansmire, and Bernard (1997); asymmetry in beef, lamb and pork in farm-retail price transmission in Australia by Griffith and Piggott (1994) and asymmetry in farm to retail price transmission of fresh tomatoes, onions, powder milk, soluble coffee, rice, and beans in Brazil by Aguiar and Santana (2002).

Von Cramon-Taubadel and Fahlbusch (1994) demonstrated that an asymmetric error correction model (ECM) based on the work of Granger and Lee (1989) could be used to test for asymmetric price transmission. Von Cramon-Taubadel and Loy (1999) extended this application of the asymmetric ECM and concluded that this method was more appropriate than the use of the conventional Houck approach if the price data under investigation were cointegrated. In this light, owing to the possibility that different methods employed to detect asymmetric price transmission may lead to different conclusions, a principal objective of this paper is to analyze the behavior of tests for asymmetry according to the conventional Houck approach and to the von Cramon-Taubadel and Loy ECM approach. In this comparison, we employ monthly data over the period January 1994 to October 2002 pertaining to farm and retail prices of whole milk and two percent milk from seven US cities—Atlanta, Chicago, Dallas, St. Louis, Seattle and two cities that belonged to the Northeast Dairy Compact: Boston and Hartford.[1]

[1] The Northeast Dairy Compact was established by the Congress as an effort to restore the milk prices and assure its regional supply in six New England states. It operated from July 1997 to September 2001. Boston and Hartford enrich the analysis because this cities function under a different economic scenario, that is, in a less competitive market than the other five cities. As members of any compact, cities in the Northeast Compact were guaranteed a minimum price, which make operations less risky. Therefore, their production and marketing systems become very different than the producers that operate under more competitive markets. According to Godfrey (2001), the Northeast Compact was considered very successful because it was able to stabilize prices to milk producers and to increase revenues and production during its operation. For example, the price set in Boston was $16.94 per cwt and did not change during the compact's existence.

The comparison of these approaches not only adds to the literature on price asymmetry but also potentially adds to the robustness of the results. On the basis of this analysis, another principal objective is to estimate the elasticities of price transmission between the farm and retail levels of the marketing channel for whole milk and two percent milk by city and by model specification.

2.2 METHODOLOGY

In this section, an alternative approach for detecting asymmetric price transmission is presented. We initially present and discuss the Houck approach and subsequently we present and discuss the asymmetric ECM approach. These approaches are appropriate in examining the price transmission process between farm and wholesale, wholesale and retail, and farm and retail levels of the marketing channel. The emphasis is placed on price transmission between the farm and retail levels of the vertical market system. Additionally, while most previous studies center attention on asymmetric responses at the national level, relatively few address spatial considerations. Pick, Karrenbrock, and Carmen (1990) studied price asymmetry in the California and Arizona citrus industry; Bailey and Brorsen (1989) investigated price asymmetry in spatial fed cattle markets; and Willett, Hansmire, and Bernard (1987) look at asymmetric price response behavior of red delicious apples in the Western North Central and Northeastern regions of the United States.

2.2.1 The "Houck" approach

Houck (1977) developed a test for asymmetric price transmission based on the segmentation of price variables into increasing and decreasing phases. Many analysts followed suit; such as: Boyd and Brorsen (1988); Kinnucan and Forker (1987); Bailey and Brorsen (1989); Zhang, Fletcher, and Carley (1995); Mohanty, Peterson, and Kruse (1995); Bernard and Willett (1966); Willett, Hansmire, and Bernard (1997), Peltzman (2000); and Aguiar (2002). Houck proposed a static asymmetric model that can be written as:

$$\Delta P_{rt} = \alpha_0 + \alpha_1 \Delta P^{+}_{ft} + \alpha_2 \Delta P^{-}_{ft} + \in_t, \tag{2.1}$$

where P_{rt} and P_{ft} are retail and farm prices of the marketing chain, respectively, t = 1, 2, . . ., T, Δ is the first difference operator, and following Houck (1977),

$\Delta P^{+}_{ft} = P_{ft} - P_{ft-1}$, if $P_{ft} > P_{ft-1}$ and 0 otherwise, and $\Delta P^{-}_{ft} = P_{ft} - P_{ft-1}$, if $P_{ft} < P_{ft-1}$ and 0 otherwise.

Implicit in the development of this model is the notion that changes in farm prices are drivers of changes in retail prices. To paraphrase Kinnucan and Forker (p. 286), "farm prices are assumed to Granger cause retail prices and not vice versa." Lamm and Westcott (1981) provided evidence that for dairy products the direction of causality did indeed run from the farm level to the retail level. As shown in Tables 2.1 and 2.2, the Granger causality tests associated with the farm and retail prices of whole milk and two percent milk included in this analysis support the underlying assumption that farm prices precede or Granger cause retail prices. This support holds for all cities except Boston and Hartford, which is expected due to the price control scheme inherent in the

Northeast Dairy Compact result. This means that the pricing models can be set up with retail price as the dependent variable.[2]

Because of: (1) inertia in the food marketing system associated with storing, transporting, and processing fluid milk (Kinnucan and Forker 1987); (2) imperfections such as diversity in market structure and differences in the assimilation and transmission of information at exchange points in the market channel (Ward 1982); and (3) the nature of price reporting and collection methods (Hall *et al* 1981), the response of retail prices to changes in farm level prices generally is not instantaneous, but instead is distributed over time. Lamm and Westcott (1981) noted that six months or less is required for retail dairy product prices to adjust fully to changes in the farm price of milk. Consequently, equation (2.1), a static formulation, may be rewritten as a dynamic representation:

$$\Delta \mathrm{P}_{rt} = \alpha_0 + \sum_{i=0}^{M1} \alpha_{1i} \Delta \mathrm{P}^{+}_{ft-i} + \sum_{i=0}^{M2} \alpha_{2i} \Delta \mathrm{P}^{-}_{ft-i} + \in_t \tag{2.2}$$

The α_{1i} coefficients in equation (2.2) represent the impact of rising farm prices on retail prices, and the α_{2i} coefficients in equation (2.2) represent the impact of falling farm prices on retail prices. M1 and M2 represent the length of the lags with regard to rising farm prices and falling farm prices respectively. As such, a formal test of the asymmetry hypothesis is:

$$\mathrm{H}_0 : \sum_{i=0}^{M1} \alpha_{1i} = \sum_{i=0}^{M2} \alpha_{2i} \tag{2.3}$$

[2] The Granger Causality test is simple, it consists of regressing a variable generally labeled x on lagged values of itself and lagged values of another variable, say y. If the latter is jointly significant, we say that y Granger causes x. This is, x is preceded by y.

The appropriate test statistic then is either a t-test or an F-test owing to the fact that the respective sums in equation (2.3) constitute a linear combination of coefficients. A rejection of H_0 is evidence of asymmetry or non-reversibility in price transmission. If one fails to reject H_0, then there exists evidence to support the notion of symmetry (or reversibility) in price transmission.

2.2.2 The "Asymmetric Error Correction Model" approach

The literature dealing with price transmission for the most part has not paid proper attention to the time-series properties of the data (Goodwin and Holt 1999). That is, with few exceptions, previous research, at least in the agricultural economics literature, has not considered the inherent nonstationarity of prices or long-run stationary equilibria (cointegration) relationships among prices. This limitation was recognized by von Cramon-Taubel (1998) in investigating asymmetric price behavior in German producer and wholesale hog markets. Goodwin and Holt (1999) evaluated price linkages among producers, wholesale, and retail marketing channels in US beef markets utilizing threshold cointegration methods introduced by Balke and Fomby (1997). Similarly, Goodwin and Harper (2000) investigated linkages among farm, wholesale, and retail markets utilizing cointegration techniques in analyzing price transmission, threshold behavior, and asymmetric adjustment in the US pork sector. Finally, Goodwin and Piggott (2001) evaluated linkages among four corn and four soybean markets in North Carolina using cointegration methods.

The asymmetric ECM approach is motivated by the fact that none of the variants of the aforementioned Houck approach are not consistent with cointegration between the retail and farm price series (von Cramon-Taubadel 1998; von Cramon-Taubadel and Loy 1999). If P_{rt} and P_{ft} are cointegrated, then by the Engle-Granger Representation Theorem, we may develop an alternative specification for the price transmission process.

Granger and Lee (1989) propose a modification to equation (2.4) that involves a Wolfram-type segmentation of the error correction term ECT into positive and negative components:

$$\Delta P_{rt} = \beta_0 + \beta_1 \Delta P_{ft} + \beta_2 ECT_{t-1} + \sum_{i=1}^{P_1} \beta_{3i} \Delta P_{rt-i} + \sum_{i=1}^{P_2} \beta_{4i} \Delta P_{ft-i} + v_t \qquad (2.4)$$

where $ECT_t = P_{rt} - \gamma_0 - \gamma_1 P_{ft}$ (residuals from the cointegration relation between P_{rt} and P_{ft}). P_1 and P_2 represent the length of the lags associated with the change in retail series and the change in the farm price series.

$$\Delta P_{rt} = \beta_0 + \beta_1 \Delta P_{ft} + \beta_2^{+} ECT_{t-1}^{+} + \beta_2^{-} ECT_{t-1}^{-} + \sum_{i=1}^{P_1} \beta_{3i} \Delta P_{rt-i} + \sum_{i=1}^{P_2} \beta_{4i} \Delta P_{ft-i} + v_t \qquad (2.5)$$

Von Cramon-Taubadel and Loy (1999) made further modifications to this equation to allow for the segmentation of ΔP_{ft}. Consequently, the asymmetric error correction model in our analysis is given by:

$$\begin{aligned}\Delta P_{rt} = {} & \beta_0 + \beta_1^{+} \Delta P_{ft}^{+} + \beta_1^{-} \Delta P_{ft}^{-} + \beta_2^{+} ECT_{t-1}^{+} + \beta_2^{-} ECT_{t-1}^{-} + \\ & \sum_{i=1}^{P_1} \beta_{3i} \Delta P_{rt-i} + \sum_{i=1}^{P_2} \beta^{+}{}_{4i} \Delta P^{+}{}_{ft-i} + \sum_{i=1}^{P_3} \beta^{-}{}_{4i} \Delta P_{ft-i} + v_t\end{aligned} \qquad (2.6)$$

Subsequently, we may rewrite and operationalize equation (2.6) as:

$$\Delta P_{rt} = \beta_0 + \sum_{i=0}^{P_2} \beta_{4i}^{+} \Delta P_{ft-i}^{+} + \sum_{i=0}^{P_3} \beta_{4i}^{-} \Delta P_{ft-i}^{-} + \beta_2^{+} ECT_{t-1}^{+} + \beta_2^{-} ECT_{t-1}^{-} + \sum_{i=1}^{P_1} \beta_{3i} \Delta P_{rt-i} + v_t \tag{2.7}$$

Notice that equation (2.7) is similar to the Houck approach given by equation (2.2), except for three additional terms: $\beta_2^{+}\mathrm{ECT}_{t-1}^{+}, \beta_2^{-}\mathrm{ECT}_{t-1}^{-}$ and $\sum_{i=1}^{\mathrm{P}_1} \beta_{3i}\Delta\mathrm{P}_{rt-i}$. Thus, the asymmetric ECM nests the Houck model. If any of the coefficients β_2^{+}, β_2^{-}, and $\beta_{3i} (i = 1, ..., \mathrm{P}_1)$ are statistically different from zero, then the asymmetric ECM is statistically superior to the Houck model. A formal test of the asymmetry hypothesis using equation (2.7) is:

$$\mathrm{H}_0 : \sum_{i=0}^{\mathrm{P}_2} \beta_{4i}^{+} = \sum_{i=0}^{\mathrm{P}_3} \beta_{4i}^{-} \text{ and } \beta_2^{+} = \beta_2^{-} \tag{2.8}$$

Again, because equation (2.8) involves a linear combination of structural coefficients, a joint F-test can be used to test the null hypothesis of symmetry in the price transmission process.

2.2.3 Elasticities of price transmission

We calculated the segmented elasticities of price transmission (EPT) for each market and product. The segmentation provides vital information about the relationship between retail and farm prices and the structure of the market. They measure the percentage change in the retail price of a commodity due to a one percent change in farm price. The elasticity of price transmission is segmented in order to capture the positive and negative changes separately.

The positive elasticity of price transmission (PEPT) is equal to:

$$PEPT= \alpha_1 * (P_{ft}/P_{rt}) \mid \Delta P_{ft} > 0 \tag{2.9}$$

The negative elasticity of price transmission (NEPT) is equal to:

$$NEPT= \alpha_2 * (P_{ft}/P_{rt}) \mid \Delta P_{ft} < 0 \tag{2.10}$$

The responsive elasticities correspond to the means of all observations for which $\Delta P_{ft} > 0$ and for which $\Delta P_{ft} < 0$; where α_1 and α_2 are the coefficients estimated in either equation (2.2) or (2.7), depending on the approach used (Houck or ECM). Emphasis on the segmentation allows businesses and firms to make better decisions on regarding pricing.

2.3. DATA

Monthly nominal retail prices of two percent and whole milk and undeflated announced cooperative (farm level) blend prices for milk from seven U.S. cities for the period January 1994 to October 2002 were used. To create a farm price for whole milk and a farm price for two percent milk, adjustments to the cooperative blend price were made based on butterfat and components.[3] Our analysis was conducted using 106 monthly observations. Atlanta, Boston, Chicago, Dallas, Hartford, Seattle, and St. Louis were chosen to represent different regions of the country to achieve geographic diversity; Boston and Hartford were also chosen because they belong to the Northeast Compact. Descriptive statistics associated with these respective price series are exhibited in Tables 2.3 and 2.4. The farm and retail prices are expressed in terms of

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[3] We are grateful to Bud Schwart, Extension Dairy Economist at Texas A&M University, for making these adjustments to the blend price.

dollars per gallon. The source of the data is the Agricultural Marketing Service, U.S. Department of Agriculture.

Average farm prices of whole milk range from $1.28 per gallon (Seattle) to $1.46 per gallon (Boston). Average retail prices of whole milk range from $2.63 per gallon (Dallas) to $3.29 per gallon (Seattle). Similar figures are evident for average farm and retail prices of two percent milk across these seven U.S. cities. Suffice it to say that noteworthy differences exist in prices, both at the farm and retail levels, for the seven cities. In short, differences in farm and retail prices, as well as in farm-retail price spreads by city, are likely the results of government policy and the cost of transporting fluid milk from surplus to deficit areas.

The next step is check on the cointegration between the respective farm price and retail price series.[4] In Tables 2.5 and 2.6, we summarize the Johansen cointegration tests. Based on both the Trace test and the Maximal Eigenvalue test statistics, farm prices and retail prices of whole milk are cointegrated for the cities of Atlanta, Chicago, and Dallas. Farm prices and retail prices of two percent milk are cointegrated for all cities except Boston and Hartford. Consequently, in order to capture the long term relationship for the respective cointegrated series, we apply the asymmetric ECM, which is more robust than the Houck approach.

Again, we speculate that the lack of cointegration of farm and retail prices in Boston and Hartford may be attributed to the institution of the Northeast Compact.

[4] The Johansen Test (Johansen and Joselius 1990 and Johansen 1995) is conducted in two steps. First, the Augmented Dickey Fuller is used to check for stationary properties of the series.

Bailey (2003) found that retail prices were higher by roughly 30 to 31 cents per gallon in these cities when the Northeast Compact was in effect compared to when it was not. Also, Bailey (2003) found that the farm-to-retail price spread was higher during the presence of the Northeast Compact.

2.4 ESTIMATION PROCEDURES

To accommodate the Houck approach, we estimate equation (2.2) for the milk products and the seven representative cities. Similarly, we estimate equation (2.7) to accommodate the ECM approach for those cities with cointegrated prices. Except for Boston and Hartford, roughly 40 (60) percent of the observations are for decreases (increases) in farm prices. In the cases of Boston and Hartford, the observations are roughly evenly split for decreases in farm prices and for increases in farm prices. Thus from a statistical standpoint, a sufficient number of observations exist to reliably assess the asymmetry issue.

In some of the equations, serial correlation is evident; therefore, for these equations, generalized least squares estimates are presented. In those equations in which serial correlation is not evident, we present ordinary least squares estimates. Lag structures associated with the Houck approach and the ECM approach were estimated using the Almon procedure. Lag structures were assumed to lie on a second order polynomial. Endpoint restrictions were used in conjunction with the Almon procedure. The length of the distributed lag process was determined based on the Akaike

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Second, for those series that were integrated of the same order, we use the Johansen test to check

Information Criterion (AIC) and the Schwarz Information Criterion (SIC). The level of significance for this analysis is the 0.05 level.

2.5 EMPIRICAL RESULTS

The estimated coefficients and their estimated p-values associated with the Houck approach and the ECM approach for whole milk and for two percent milk for each of the seven cities are exhibited in Tables 2.7-2.11.[5] Estimated coefficients in most cases are statistically different from zero and are in accord with a priori expectations. For the equations corresponding to the Houck approach, the goodness-of-fit statistics range from 0.1682 to 0.4342, and for the equations corresponding to the ECM approach, the goodness-of-fit statistics range from 0.20 to 0.47. The relatively low magnitudes of these R^2 statistics are attributable to the fact that the dependent variables correspond to changes in retail prices.

With the Houck approach, the number of lags associated with rising farm price variables typically is one, except in the cases of Seattle (whole milk and two percent milk), Dallas (two percent milk), and St. Louis (two percent milk.) The number of lags associated with declining farm price variables also is generally one, except in the cases of Chicago (whole milk) and Dallas (whole milk and two percent milk.) This finding indicates, in contrast to Kinnucan and Forker, that the time for milk prices at the retail level to adjust to either increases or decreases in milk prices at the farm level is roughly the same.

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for cointegration.

[5] Variable definitions are exhibited in Table 2.7

However, when using the ECM approach, our results are in agreement with Kinnucan and Forker; milk prices at the retail level adjust more slowly to decreases in milk prices at the farm level, with the exceptions of Dallas (two percent milk) and Seattle (two percent milk). The lag associated with rising farm price variables is between one and three months, most commonly one month. The lag associated with declining farm price variables is between one and six months, most commonly two months.

With the Houck approach and the ECM approach, the long-run effect on retail milk prices attributable to increases in farm milk prices exceeds the cumulative effect attributable to decreases in farm milk prices. The only exceptions are in the cases of milk prices in Dallas and St. Louis. The F-test associated with the null hypothesis that retail prices respond symmetrically to increases and decreases in farm prices (equation 3) is rejected with the Houck approach in all cases except for St. Louis. With the ECM approach, the hypothesis of symmetry in price transmission (equation 8) is rejected in all cases.

Additionally, we are in a position to determine whether or not the error correction model is statistically superior to the Houck model. We consider the joint significance of B_2^+, B_2^-, and B_{3i} (i=1, . . . P_1) in equation (2.7). The F-statistic is the basis of this test, assuming the lag structures are the same for ΔP_{ft}^{+} and ΔP_{ft}^{-}. If the lag structures are not the same, then one may use either the Akaike Information Criterion (AIC) or Schwarz Information Criterion (SIC) to make the statistical comparison between model specifications. For whole milk, the Houck model and the error correction model are statistically equivalent. For two percent milk, the same inference holds for Atlanta, Chicago, and Dallas. However, for Seattle and St. Louis, in the case of two percent milk, the error correction model is statistically superior to the Houck model, since ECM captures the long term relationship between farm and retail prices.

Short- and long-run elasticities of price transmission, evaluated at the sample means of the data, are exhibited in Tables 2.12-2.15 for rising and falling farm prices. All estimated elasticities of price transmission are less than the elasticity of price transmission of 0.9375 reported by George and King (1971). The long-run elasticities of price transmission are at least twice as large as the corresponding short run elasticities of price transmission. This result holds for both increases and decreases in prices at the farm level. For rising farm prices of milk, the elasticities of price transmission vary from 0.037 to 0.263 in the short-run and from 0.187 to 0.527 in the long-run. For falling farm prices of milk, the elasticities of price transmission vary from 0.005 to 0.166 in the short-run and from 0.031 to 0.553 in the long-run. Kinnucan and Forker (1987) reported the elasticity of price transmission for rising farm prices of milk to be 0.274 in the short-run and 0.462 in the long-run. For falling prices of milk, they found the elasticity of price transmission to be 0.184 for the short-run and 0.330 for the long-run. Their short-run elasticities of price transmission are outside our intervals, but their long-run elasticities of price transmission are within our intervals.

Except for Dallas (whole milk and two percent milk) and St. Louis (two percent milk), elasticities of price transmission are greater for rising farm prices then for falling price prices. Thus, in most regions, consistent with Kinnucan and Forker (1987), increases in the farm price of milk are passed through to the retail level more fully than are decreases in the farm price of milk.

2.6 CONCLUDING COMMENTS

We analyze the behavior of spatial tests of asymmetric price transmission according to the conventional Houck approach and to the von Cramon-Taubadel and Loy ECM approach. Empirical results suggest that the farm-retail price transmission process for milk is asymmetric. This result holds true for each of the seven cities considered in our analysis. In most cases, the Houck approach and the ECM approach, (where applicable) are statistically indistinguishable. The exceptions are two percent milk for Seattle and St. Louis. With the ECM approach, milk prices at the retail level adjust more slowly to decreases in milk prices and more quickly to increases in milk prices at the farm level. This conclusion is not supported by the Houck approach. In most cases, price transmission elasticities for rising farm prices are generally larger than corresponding elasticities associated with falling farm prices for both the Houck approach and the ECM approach. The short-run elasticities of price transmission for milk products are smaller in magnitude compared to those reported in the literature. The long-run elasticities of price transmission are consistent with those reported in the literature.

However, one of the main limitations of this research is the assumption that there are no intermediaries between the farmer and the retailer. There is a possibility that some other agents are generating the rigidity of price transmission.

Having asymmetric price transmission means that social welfare is not being maximized. For example, when farm prices are going down, consumers should benefit from it. However, our results indicate that they are not because retailers do not respond to farm price reductions in the same way as they do to farm price increases. Retailers are taking some of the surplus from consumers, thereby diminishing the maximization of their surplus and thus the social welfare. Under this scenario, policies may be needed to correct this market failure and to assure that consumers are not harmed by non competitive market practices.

We recommend that in future studies of asymmetry and elasticities of price transmission that: (1) consideration be given to the ECM approach in addition to the conventional Houck approach; and (2) the analysis be conducted on a spatial basis, either by city or region in lieu of a national analysis. Our empirical results suggest that differences in inferences not only are possible but also in fact do occur by geographical area.

CHAPTER III

STOCK MARKET REACTION TO A PARTICULAR DISEASE OUTBREAK: AN EMPIRICAL APPLICATION FOR AN EVENT STUDY IN THE FOOD SUPPLY CHAIN

3.1 BACKGROUND

Today, agricultural firms have more opportunities to reach and interact with foreign markets. In the case of the food industry, market integration and product diversity bring new challenges, such as product safety. This is an important issue for economists to address. Firms will implement safety practices if the benefits of doing it are higher than the costs. This is, if businesses expect higher profits from their products or reduce the risk of an outbreak through the adoption of safety practices, they will have incentives to implement them.

Economists are qualified to answer questions such as: what is the optimal level of safety a firm should adopt? What are the incentives for private and public safety? What is the economic impact when safety goes wrong? What is the impact throughout the supply chain? And, what are the most cost effective measures for recovery after existing safety measures have failed?

In order to address some of these questions, economists have been developing different tools. For example, event study methodology aids in evaluating how unexpected events, such as changes in safety patterns, impact the value of the firm.

These event studies consist of evaluating the economic impact of a particular episode on the value of the firm, which is reflected in the rate of return of the firm's stock.

A publicly traded company is not only interested in maximizing the wealth of its investors but also in minimizing their risk. Thus, this paper extends the traditional methodology to study how a particular event affects risk to the firm and if there are spillover effects on the industry.

This chapter relies on the foundation of the event study methodology to explore how one of the worst food disease outbreaks in the United States affected the main players involved. Studying this outbreak is important to understand how markets and economic agents react to unexpected disease outbreaks in the agriculture and food industry. The event explored here involves some of the most important firms in these sectors.

This chapter is divided into several sections. First, an extensive literature review is presented. This section covers previous theoretical and empirical studies that provide the best available methodology for this work. Second, the event study is described. Third, the simple market model used to calculate and test for abnormal rates of returns for the companies involved in the outbreak is developed. In addition, a GARCH model is applied to the simple market model to account for time-varying volatility. Then, a Seemingly Unrelated Regression (SUR) is built to check for spillover along the supply chain. This technique is used to capture the impact on other firms after the outbreak. Finally, conclusions are presented.

3.2 LITERATURE REVIEW

Extensive economic and financial literature on event studies exists. Although MacKinlay (1997) reported that the first published work on this topic was the paper by Dolley (1933), perhaps Sharpe (1964) has made the most important contribution to event study literature. Sharpe (1964) used the previous work of Markowitz (1959) to provide the first aggregate market model that could be used under conditions of risk. The application of the simple market model became the conventional tool for economists to perform event studies.

The simple market model captures one of the main rationales regarding financial markets: the value and risk of a firm's security are a function of the company's market performance. Thus, the simple market model aids in calculating how a relevant event related to a company affects the value and risk of its stock.

Most of the literature on event studies relies on the same structure and methodology. It is the econometric technique and data periodicity that varies among papers. MacKinlay (1997) summarized different methods for performing event studies and provided different procedures to conduct an event study. Two points of importance are derived by MacKinlay (1997): one, the clear definition and understanding of the event, and, two, the correct use of data. Brown and Warner (1985) and MacKinlay (1997) discussed the performance of different frequencies of observations. Particularly, Brown and Weinstein (1985) showed that using daily rates of return provides more robust results compared to less frequent data, such as quarterly rates. They argued that daily frequencies carry more information. However, researchers must be aware of certain difficulties, such as autocorrelation and heteroskedasticity. MacKinlay (1997) suggested that when testing for abnormal returns using the market model, it is better to use daily frequencies and a sample which spans from over 120 days before the day of the event to twenty days or more after the event. As an illustration, MacKinlay (1997) used the simple market model to evaluate quarterly earnings announcements for 30 firms in the Dow Jones Industrial Index from 1989 to 1993. MacKinlay calculated abnormal rates of returns due to the announcements for each of the firms. Abnormal return is the difference between ex post observed return of the security minus the expected return prior to the event.

Another important contribution to the literature was made by Binder (1998), who elaborated a detailed event study methodology since 1969. In his work, he discussed different methods for calculating abnormal rates of returns along with other statistical problems, such as heteroskedasticity and serial correlation, which generate yield inefficient and invalid statistical inferences on the systematic risk's estimated coefficients.

Event studies have been applied in a wide variety of industries. To illustrate, Marcus et al (1987) studied the impact of drug recalls on that firm's stock value. They found that drug recalls had a more severe negative effect on the stock value of the firm than did the direct cost borne by the firm. Chugh et al (1978) examined how the air and water pollution control legislation (1953-75) directly affected the financial risks and costs of chemical, electric utilities, iron and steel, petroleum, and textile industries. They found that companies have higher risks and a higher break-even point due to higher environmental standards. Ries (1993) analyzed the impact of the voluntary export restraint agreement (VER) on Japanese automobile stock prices. Andersen et al (2003) analyzed how the exchange rates adjust to news. They found that conditional means of US dollar exchange rates adjust to news faster than the conditional variance.

In addition, different econometric techniques have evolved over time for conducting event studies. For example, Corhay and Tournaid (1996) introduced a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) within the market model to capture time-varying volatility and used it to estimate abnormal rates of returns. Their event study analyzed divestitures of Dutch firms. They used 140 observations prior to the event and 20 after, which is consistent with the event interval used in MacKinlay (1997). Corhay et al (1996) found that using OLS versus GARCH leads to different results and different interpretations. A similar approach is performed by Wang et al (2002) who incorporated a multivariate GARCH technique to account for time-varying volatility for an event study related to food contamination recalls between two firms positioned at the same point in the supply chain. On the same token, Salin and Hooker (2001) studied how time varying volatility of the firm changes due to food recalls. They use two approaches to analyze volatility: first, they use the standard deviation of daily returns, and, second, they computed a daily price spread and normalized it over daily opening stock prices to capture price movements within the day. In that particular study, they found that the events did not generate volatility in all cases. However, they did find that food recalls affected the value of the firms.

Thompson (1985) developed a system of equations to capture the interrelationship among securities under an event study. The structure he used is Seemingly Unrelated Regressions (SUR). His paper contains a detailed description of the structure of the system and the technique to estimate and test the hypotheses of significance for the parameters. da Graca (unpublished dissertation, 2002) suggested that using Generalized Least Squares (GLS) is more powerful than using Ordinary Least Squares because GLS technique will generate more efficient coefficients. In his event study on Brazilian privatization auction events, he finds different results between conducting OLS and GLS. However, this might not be true under a system of equations. Thompson (1985) argues that although there are some benefits under GLS in an event study, there are problems if the covariance matrix of the error is not known. If the error is estimated, it is not clear if using GLS is advantageous. Thus, Thompson (1985) contradicts the conclusions of da Graca (2002), who strongly suggests the use of the GLS approach. However, if the correct variance-covariance matrix of the error is known, GLS will produce more efficient estimated parameters.

There are other methodologies suggested in the literature. For example, Kramer (2001) proposed an alternative method for performing event studies using nonparametric econometrics, which for this case consists of normalizing the data through bootstrap re-sampling. She suggested this method would improve results since in some cases time series data does not maintain a normal distribution. In this same context, some other authors, such as Marais (1984), use bootstrap techniques in event studies. Cable and Holland (1999), along with Larsen and Resnick (1999), showed that under the simple market model, regression derives better results than those produced by non-regression techniques.

Although, there is extensive literature on empirical applications of the market model, there are some topics which have either not been covered well enough or not at all. For example, the use of the market model to analyze spillovers along the supply chain has not been reported. In addition, we believe that more research on the market model and volatility needs to be done.

3.3 METHODOLOGY

3.3.1 The simple market model and abnormal returns

The daily rate of return on a stock is an indicator of the relative change in the market value of a publicly traded company. The firm's value changes over time, depending on the company performance. Investors use the media as one of the most important sources of monitoring this performance. Quarterly earnings, acquisitions, alliances, dividends, new technologies, and good and bad events reported by the media are used by investors to decide how much of a company's stock they will buy or sell, determining the stock market price of a particular firm.

Sharpe (1964), who followed the work of Markowitz (1959), was the first to develop a market model of equilibrium asset prices under conditions of risk. The simple market model illustrates that expected return from asset *i* is a function of the return of the market portfolio. MacKinlay (1997) expressed the market model for company *i* as follows:

$$r_{it} = \beta_0 + \beta_1 r_{mt} + \varepsilon_{it}, \tag{3.1}$$

where r_{it} is the rate of return of company *i* in time *t*. The variable r_{mt} is the rate of return of a well diversified portfolio, called *m*. β_0 is a constant and β_1 measures the systematic risk of firm *i*, compared with portfolio *m*. For example, if β_1 is equal to one, it means that stock *i* is as risky as portfolio *m*. If β_1 is bigger than one, it means that stock *i* is riskier than *m* and if β_1 is less than one, it means that portfolio *i* is less risky than *m*. Finally, ε is the error term.

The simple market model in (3.1) analyzes the statistical relationship between the return of a company's stock and the return of the market portfolio. MacKinlay (1997) affirms that the market model linear specification is due to the assumed joint normality of the assets return. Although prices are not stationary, returns are expected to be stationary in financial theory, which allows for their forecasts.

The simple market model provides the foundation to test for abnormal returns generated by the unexpected event. Estimating equation (3.1) allows a forecast of the return r_{it}, *h* periods ahead. According to MacKinlay (1997), this prediction is crucial to analyze the event study. He defines an abnormal return as the actual ex post return of security *i,* considering the event minus the normal return of *i*; which is equal to the return one period ahead without considering the event. This abnormal rate of return ($AR_{i,t+e}$) is the difference between the post event return $r_{i,t+e}$ and the forecast rate of return $(\hat{r}_{i,t+e})$:

$$AR_{i,t+e} = r_{i,t+e} - \hat{r}_{i,t+e}\,. \tag{3.2}$$

Technically, an abnormal return is defined as the after event return $r_{i,t+e}$ that falls out of the confidence interval (CI), calculated from the forecast rate of return $(\hat{r}_{i,t+e})$ estimated prior to the event.

$$CI = \hat{r}_{i,t+e} \pm t_{cv} \times se(r_{i,t}) \tag{3.3}$$

where t_{cv} is the critical value, $se(r_{i,t})$ is the standard error of the entire pre-event period regression.

3.3.2 The market model and volatility

Analyzing time varying volatility is important in the study of financial markets. The simple market model can be extended to analyze the volatility originating in the series due to an outbreak. If the volatility of the return increases after an unexpected event, investors would expect higher rates of return as a compensation for holding a risky asset. A common technique to analyze volatility was developed by Engle (1982). In his paper, he proposed a model with a stochastic process called autoregressive conditional heteroskedasticity (ARCH) which allows the use of recent past information to forecast the variance one period ahead. Moreover, Bollerslev (1986) developed an econometric model that captures the previous variance to build the current conditional variance equation. This generalization of the ARCH model is known as a Generalized ARCH or GARCH model, which consists of a mean and conditional variance equation.

Corhay et al. (1996) and Wang et al. (2002) use a market model which uses GARCH to account for time varying volatility effects. Wang et al. (2002) argue that this econometric technique provides important information about the level of return and its variance at the same time. The market model should be adjusted for GARCH effects when the residuals of equation (3.1) are heteroskedastic. This is because recent past errors may give information on the conditional variance since it is based on past information.

Thus the GARCH (p,q) specification for the market model is:

$$r_{it} = C_i + \beta_i r_{mt} + \varepsilon_{it}\text{, where} \tag{3.4}$$

$$\varepsilon_{it} \mid \psi_{i,t} \sim \mathrm{N}(0, \mathrm{h}_{\mathrm{it}})\text{, and} \tag{3.4'}$$

$$h_{it} = \alpha_{i0} + \sum_{k-1}^{q} \alpha_{ik} \varepsilon_{i,t-h}^2 + \sum_{j=1}^{p} \theta_{ij} h_{i,t-j}\,. \tag{3.5}$$

Equations (3.4) and (3.5) are the mean and variance equations, respectively. The mean equation is expressed as a function of the exogenous variables and an error term ε_{it}. Equation (3.4') contains the information set $\psi_{i,t}$ at time *t* for firm *i*. Equation (3.5) is called the conditional variance equation, since h_{it} is conditional based on past information. The variable $\varepsilon_{i,t-h}^2$ captures volatility from previous periods. N is the distribution of the residuals and with p > 0; α_{ik}>=0, i=0,…p; q>0; b_{ij} >= 0, j=0,…q.

3.3.3 The simple market model and spillovers in the market

The methods described to this point are used to identify the effect of an event on a single firm's return. It is also of interest to analyze spillovers across the industry related to this event. Within a market, there are producers, sellers, and consumers; it is important to see how an event passes through these economic agents. Specifically, we explore how an event that involves firm *i* is affecting firm *j* and others. Thus, it is useful to develop a system of equations to capture contemporaneous correlation that may lead us to find spillovers. An extension of the simple market model (3.1) is performed to capture interrelated information from one security to another using a Seemingly Unrelated Regression (SUR) technique. The parameters capture the correlation of residuals among companies in the same industry.

Thompson (1985) performs a system of equations of an event study to take into account spillovers through an aggregation of the basic market model, where equation (3.1) is rewritten in matrix notation as follows:

$$R = Z\Gamma + E \tag{3.6}$$

where

$$R_{(nj)\times 1} = \begin{bmatrix} \underline{R_1} \\ . \\ . \\ \underline{R_j} \end{bmatrix} \qquad Z_{(nj)\times 3j} = \begin{bmatrix} \overline{Z_1}........0 \\ 0...\overline{Z_2}..... \\ 0..........\overline{Z_j} \end{bmatrix} \qquad \overline{Z_j} = [1, \underline{R}_m, \underline{D}_1]_{nj\times 3}$$

$$\Gamma_{(3j\times 1)} = \begin{bmatrix} \alpha_1 \\ \beta_1 \\ \underline{\gamma_1} \\ . \\ . \\ .\alpha_j \\ \beta_j \\ \underline{\gamma_j} \end{bmatrix} \qquad E_{(nj\times 1)} = \begin{bmatrix} \underline{e}_1 \\ . \\ . \\ \underline{e}_j \end{bmatrix}$$

where an underscore indicates a vector and an over score indicates a matrix. R is a column vector that contains j blocks with the daily rates of return ($\underline{R}_j$) for each of the j companies in the model; n is the number of observations for each of the j companies. $\underline{R}_j$ is a vector of (n x 1). Z is a block diagonal matrix that contains the blocks ($\overline{Z_j}$) of dependent variables: the intercept 1, the rate of return of the well diversified portfolio ($\underline{R}_m$) and the binary variable with the announcement dates (D_j). Each of these vectors is (n x 1). Γ is the column vector which contains the coefficients for the dependent variables and E is the error column vector. Thompson (1985) suggests specifying this model as Seemingly Unrelated Regressions (SUR), treating each equation separately and specifying each using Ordinary Least Squares (OLS). His paper argues that OLS, in comparison to GLS, is less efficient when the variance covariance matrix is known. However, if it is not known, it is not clear whether using GLS provides any advantage. For the particular case of our study, the SUR was simultaneously estimated to capture the contemporaneous correlation of the disturbances among equations, in order to obtain associations among firms, if any exist.

3.4 DESCRIPTION AND CHRONOLOGY OF THE EVENT CASE STUDY

The particular event study performed in this work deals with one of the worst outbreaks of foodborne diseases in the United States and its impact on the value of the firms that were involved in the unexpected episode. There are two main companies involved in this outbreak: Prandium and Sysco.

Prandium was founded in 1999 after a merger between Koo Koo Roo, Inc. and Family Restaurants, Inc. Prandium was the holder of the largest Mexican chain restaurants in the US: Chi-Chi's.

On the other hand, Sysco is one of the largest food distributors to the foodservice industry. Sysco's products and services are distributed to more than 390,000 customers, including Chi-Chi's.

These companies are positioned in different places along the supply chain. Sysco, as a food distributor company, is placed one step before Prandium, the restaurant holder, in the supply chain.

The chronology of this event is as follows: on November 3, 2003, the Associated Press reported a hepatitis advisory to all people who ate at Chi-Chi's restaurant in Beaver Valley, Pennsylvania, between October 22 and November 2. At that time, Chi-Chi's was heading for auction with more than $100 million in debt and had already filed for Chapter 11 bankruptcy in the US Bankruptcy Court in Delaware on October 8, 2003.

The Associated Press and the Pittsburgh Post-Gazette reported the evolution of the event. When the State Department of Health issued the public notice, at least 12 restaurant workers and 10 consumers were infected. By November 7, only a few days later, the number of cases had risen to 130, the first customer died, and one more needed a liver transplant. Individual law suits started to rise to almost 40 through Marler Clark, a law firm specializing in representing victims of foodborne illness (marlerclark.com). Marler Clark filed a class action lawsuit against Chi Chi's on behalf of over 9,000 people who were forced to receive Immune Globulin injections to prevent infection with hepatitis A after being exposed to the virus at Chi-Chi's.

By November 11, the number of cases had risen to 300, which is above the average number of Hepatitis A cases in a restaurant outbreak reported by the Centers for Disease Control and Prevention. By November 19, the number of cases was more than 500 and three people had died. On this date, the United States Department of Agriculture banned the importation of Mexican green onions due to the suspicion that the onions had caused the hepatitis outbreak.

As a precautionary measure and to assure the safety and trade of Mexican products, the Mexican government closed four green onion farms until an investigation was completed (Calvin et al 2004). On November 21, the *Reforma* newspaper in Mexico published an interview with Baja California agriculture officials speaking out in defense of the growers. They said that no evidence linked any of the four farms to the outbreaks that had infected more than 500 people and killed three who ate raw green onions served in salsa at a Chi-Chi's restaurant in Pennsylvania.

However, according to Thomas (2003), by November 27 the accusations against the Mexican onions had neither been proven nor confirmed by experts; this made the Mexican government and producers upset about being blamed as the source of the outbreak. In an article published on November 28, 2003 in Periódico Reforma, the governor of Baja California, Eugenio Elorduy, started to speak out on behalf of the onion producers located in that state. Governor Elorduy rejected the attitude of the US government. He welcomed all American inspectors to come to Mexico to review the evidence since he was confident that the growers had used the right procedures to produce the onions.

By the middle of December, a dispute between the Mexican and US Government erupted. On December 11, 2003, there was an article in the Pittsburgh Post-Gazette by Christopher Snowbeck arguing that Mexican and US authorities had been sending confusing signals to the market. The Mexican authorities denied that the source of the outbreak originated in Mexico, claiming that it was due to mishandling and storing by Chi-Chi's, and the US authorities were blaming Mexico without evidence.

On December 15, an article in the San Diego Union-Tribune written by staff members Diane Lindquist and Sandra Dibble raised the possibility that the outbreak originated in Mexico, but they acknowledge that this was impossible to confirm. Jack Guzewich of the US Food and Drug Administration said that investigators may never know the origin of the outbreak for certain. This further upset the Mexican authorities, who accused the FDA of negatively affecting the image of Mexican products by pointing to Mexican farmers while admitting they had no real evidence to back up their claims about the source of the outbreak.

Finally, the Pittsburgh Post-Gazette reported that the event sickened around 660 people and killed four. After the FDA failed to find evidence that the Mexican growers were the source of contamination, Chi-Chi's went after the suppliers: Sysco and Castellini, encouraging them to help pay part of the cost. However, since neither of these companies wanted to pay for it, Chi-Chi's proceeded to sue them late in July of 2004 through Gordon's law firm. There are no public records which show the exact date of the trial. The first public document on this lawsuit was published on August 3, 2004, by the Associated Press and released by several newspapers. Each of these articles only mentions that the lawsuit took place sometime at the end of July. After an intense investigation, it was not possible to find a document with the date of the trial. According to our investigation, it is likely that the parties settled the dispute outside the court room.

3.5 DATA

All of the data came from Yahoo® Finance Services. Rates of returns were computed for each company. The frequency was daily and expressed in decimal changes. The S&P 500 was used as a proxy for a well diversified market portfolio return. We followed MacKinlay (1997) to establish the data range: 120 observations prior to the event and 20 after.

The event study for this work has two major episodes: first, when Prandium, holder of Chi-Chi's, was publicly implicated in the outbreak on November 3, 2003;

second, when the Associated Press reported that Prandium had sued Sysco on August 3, 2004.

Thus, there are two sets of data: one for the event of November 3, 2003, in which Prandium was involved. The other data set corresponds to the notice that appeared on August 3, 2004, in which Sysco was involved. Descriptive statistics associated with these respective price series are exhibited in Tables 3.1 and 3.2. Related graphs for each series of returns are displayed in Figures 3.1 and 3.2.

It is important to note that Prandium data presents the highest standard deviation among all securities. The riskiness of Prandium and its financial problems caused this company's daily returns to fluctuate from -38.82 to 282.35 percent, as it is shown in Table 3.2 and Figure 3.1. In addition, the riskiness of Pradium is shown in Figure 3.1, where Prandium's rates of return oscillate highly compared to the S&P 500.

On the other hand, Sysco presents a small standard deviation, which reflects a very low level of risk. Sysco's rates of return move somewhat close to the S&P 500, as can be observed in Figure 3.2.

Finally, one additional set of data is considered to estimate spillovers of one firm's safety breach on its industry. The firms considered for this multivariate system are publicly traded firms that are competitors with Sysco and Prandium. This allowed us to incorporate a diversity of firms positioned in different locations along the supply chain; some closer to the final consumers than others.

The following firms were considered Sysco's clients and Prandium's competitors: Brinker International Inc. (EAT) that owns and operates Chili's Grill and

Bar, Romano's Macaroni Grill and On the Border Mexican Grill. Darden Restaurants Inc. (DRI) runs Red Lobster and the Olive Garden, among other restaurants. Outback Steakhouse Inc. (OSI) owns and manages Outback restaurants. Finally, Applebee's International Incorporated (APPB) owns and operates Applebee's Restaurants.

The following were considered competitors for Sysco: Performance Food Group Company (PFGC), Aramark (RMK), Ahold (AHO), which is the parent company of US Food Service Inc. and Supervalu Foods Inc. (SUV). These companies, including Sysco, share the majority of the American market in food distribution.[6]

3.6 ESTIMATION PROCEDURE

The first procedure was to estimate the simple market model for Prandium and then for Sysco.

3.6.1 Simple market model for Prandium

As described in Section 3.2, the first announcement that involved Prandium was published on the 4th of November, 2003, the day that the Associated Press issued the first public note regarding a hepatitis contamination at Chi-Chi's. Using MacKinlay (1997) methodology, 120 observations are used to estimate the pre-event simple market model for Prandium.

The results are shown in Table 3.3. The Beta coefficient is 1.502. Although it is not statistically significant, the magnitude and sign of the coefficient makes sense and corresponds to what it is observed in Figure 3.1. Prandium is more volatile than the

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[6] For detailed information on these firms, please see Appendix B, pp. 110.

S&P. That is, Prandium stock is riskier than a well diversified portfolio. Due to the catastrophic financial situation of Prandium, related to its bankruptcy mentioned in Section 3.4, the rates of returns of this company were unable to generate the results needed to do any further market analysis.

The next step is to study the other major player involved in the outbreak: Sysco, Prandium's supplier.

3.6.2 The augmented market model for Sysco

For Sysco, the event day is August 3, 2004, the day that the press announced that Prandium intended to sue its supplier. In order to study Sysco, the simple market model was augmented by adding some binary variables, to capture some company specific announcements, such as quarterly earnings reports and acquisitions. Thus the augmented market model for Sysco is:

$$r_t = \beta_0 + \beta_1 r_{mt} + \beta_2 D_{1t} + \beta_3 D_{2t} + \varepsilon_t \tag{3.7}$$

The first binary variable (D_1) has a value of 1 on the day Sysco announced quarterly reports, sales records, and dividends; D_1 is 0 for all other days in the period. D_2 takes the value of 1 the day that Sysco completed and reported asset acquisitions and is 0 elsewhere. The reason for having two dummy variables is that the expected signs for the coefficients are different. Quarterly reports, sales records and dividends are expected to be positively correlated to r_t, while acquisitions are expected to be negatively correlated. The announcements are reported in Figure 3.2. The White test was used to test for heteroskedasticity; the results are reported in Table 3.4. The null hypothesis of no heteroskedasticity fails to be rejected. Thus, equation (3.7) can be estimated using Ordinary Least Squares; the results are reported in Table 3.3.

The results presented in Table 3.3 show a significant β_1, which is the systematic risk of Sysco. The magnitude of this coefficient is 0.573. Since this is less than one, this means that the stock of this company is less risky than the market portfolio.[7]

Also, the signs of the coefficients for D_1 and D_2 are what we were expecting. For example, the positive sign of the coefficient D_1 indicates that the daily rates of returns moved in the same direction as the quarterly and dividend reports. This is, when there are announcements on dividends going up, the rate of return goes up as well. On the other hand, the sign of D_2 is negative as expected. This is because the company is increasing the costs in the short term by acquiring assets, thus short term investors lose incentives to invest in the company because it will take time to generate profits.

In order to calculate and test the significance of Sysco's abnormal rates of return associated with the public announcement of the lawsuit, results from equation (3.7) were used to compute equations (3.2) and (3.3). In order to compute the abnormal rate of return for the event day, we use the pre event day's rate of return (August 2, 2004) to forecast one period ahead the rate of return $(\hat{r}_{i,t+e})$. Thus, the abnormal rate of return for the event day is the difference between the observed rate of return on the event day

[7] It is important to note that some risk has been already captured by the dummy variables D_1 and D_2.

($r_{i,t+e}$), minus the forecast rate of return $(\hat{r}_{i,t+e})$ estimated prior the event, as expressed in equation (3.2). We do this for the event day in addition to the next four consecutive days.[8] Results are displayed in Table 3.5. None of these days presented abnormal returns. All the forecasted returns fall inside the confidence interval of the forecast. For example, for the day of the announcement, August 3, 2004, the forecasted return is +.0017 and the actual rate of return is -0.007. The abnormal return is -.008, which however, falls within the 95 % confidence intervals of the forecast.

The same applies for the next four days after the announcement. The hypothesis of abnormal rates of return is rejected. That is, the market did not punish Sysco for being involved in the lawsuit related to the outbreak.[9]

3.6.3 Time varying volatility for Sysco

Time-varying volatility due to the outbreak was examined for Sysco using a GARCH approach. In order to begin, the White test was applied to check for heteroskedasticity. For this empirical exercise, we considered a total of 141 observations: 120 prior to the event, the event day, plus 20 more observation after the event. The test rejected the null hypothesis of homoskedasticity and the results are shown in Table 3.6. Residuals for the simple regression are plotted in Figure 3.3. It is immediately apparent that the last 20 observations appear to have increasing variance.

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[8] Since financial markets adjust immediately to news, we believe that there was no reason to check for abnormal returns after the fourth day of the event.

[9] Sysco's rate of return was not affected by the outbreak's news on November 3rd, 2003. Sysco was never mentioned in the media, so there is no reason for investors to lose interest or modify their position in the company.

Next, the estimation of the univariate GARCH (1,1) for Sysco was conducted. In order to do this, Wang et al (2002) specification was used, which consists of adding binary variables to equations (3.4) and (3.5). This is an augmentation of the GARCH (p,q) model presented in equations (3.4) and (3.5). More explicitly, the GARCH (1,1) model becomes:

$$r_t = \beta_0 + \beta_1 r_{mt} + d_1 D_1 + d_2 D_2 + d_3 D_3 + d_4 D_4 + d_5 D_5 + \varepsilon_t \tag{3.8}$$

$$h_t = \alpha_t + \sum_{q=1}^{1} \alpha_k \varepsilon_{t-q}^2 + \sum_{p=1}^{1} \varphi_{t-p} h_{i,t-p} + d_6 D_6 \tag{3.9}$$

Equation (3.8) and (3.9) are the mean and variance equations, respectively. The binary variables are D_1, D_2, D_3 and D_4. D_1 takes the values of 1 two days before the event day, 0 elsewhere; D_2 takes the value of 1 on the event day and 0 elsewhere. D_3 takes the value of 1 two days after the event and 0 elsewhere. D_4 and D_5 capture earnings and acquisition news, respectively. They take the value of 1 the day of the news and 0 otherwise. D_6 captures the unsystematic risk after the event. This variable contains the value of zero each day before the event and 1 elsewhere. The GARCH expressed in equations (3.8) and (3.9) will capture the volatility effect, if any, due to the outbreak.

The results produced by the GARCH model in Table 3.3 are quite interesting. In the mean equation, β_1, the coefficient for the market portfolio, is statistically significant and very close to the one we obtain by using the simple market model. The three dummy variables used in this equation have the correct sign, although they are not significant. The variance equation is the forecast for variance one period ahead based on past information. This equation produced an important result since the coefficient on D_6 is statistically significant and positive. This means that after the event, the change in stock price volatility was 0.04 percent. That is, after the announcement that Sysco had been sued by Prandium, the investors were uncertain of the costs that this event was going to generate for Sysco. This behavior augmented the risk of the security.

3.6.4 Spillovers from Sysco to the industry

Finally, spillovers from Sysco to the industry were studied. The main purpose of this section is to examine if the effect on Sysco was transmitted to other firms that are positioned close to Sysco. As discussed at the end of Section 3.4, different publicly traded companies along the supply chain are considered. These are Sysco's competitors and clients. The multivariate regression from equation (3.6) becomes:

$$R = \mathrm{Z}\Gamma + E \tag{3.10}$$

where

$$R = \begin{bmatrix} R_{sys} \\ R_{appb} \\ R_{dri} \\ R_{eat} \\ R_{osi} \\ R_{rmk} \\ R_{pfgc} \\ R_{suv} \\ R_{aho} \end{bmatrix}_{(141\times 9)\times 1} \qquad Z = \begin{bmatrix} \overline{Z_{sys}}.0.0.0.0.0.0.0.0.0.0 \\ 0.\overline{Z_{appb}}.0.0.0.0.0.0.0.0 \\ 0.0.\overline{Z_{dri}}.0.0.0.0.0.0.0.0 \\ 0.0.0.\overline{Z_{eat}}..0.0.0.0.0.0.0 \\ 0.0.0.0.0.\overline{Z_{osi}}.0.0.0.0 \\ 0.0.0.0.0.0.\overline{Z_{rmk}}.0.0.0 \\ 0.0.0.0.0.0.0.\overline{Z_{pfgc}}0.0 \\ 0.0.0.0.0.0.0.0.\overline{Z_{suv}}.0 \\ 0.0.0.0.0.0.0.0.0.0.0.\overline{Z_{aho}} \end{bmatrix}_{(141\times 9)\times(4\times 9)}$$

where

$$\begin{aligned} &\overline{Z_i} = [\underline{1}, \underline{R}_m, \underline{D1}, \underline{D2}]_{141\times 4} \\ &\forall i = sys, appb, dri, eat, osi, rmk, pfgc, suv, aho \\ &0 = [\underline{0}, \underline{0}, \underline{0}, \underline{0}]_{141\times 4} \\ &\underline{R}_m = [R_m]_{141\times 1} \end{aligned}$$

$$\overline{D} = \left[D_1, D_2\right] \; \Gamma = \begin{bmatrix} \alpha_{sys} \\ \beta_{sys} \\ \delta_{sys} \\ \rho_{sys} \\ . \\ . \\ . \\ \alpha_{aho} \\ \beta_{aho} \\ \delta_{aho} \\ \rho_{aho} \end{bmatrix}_{(4\times 9)\times 1} \qquad E = \begin{bmatrix} \underline{\varepsilon}_{sys} \\ \underline{\varepsilon}_{appb} \\ \underline{\varepsilon}_{dry} \\ \underline{\varepsilon}_{eat} \\ \underline{\varepsilon}_{osi} \\ \underline{\varepsilon}_{rmk} \\ \underline{\varepsilon}_{pfgc} \\ \underline{\varepsilon}_{suv} \\ \underline{\varepsilon}_{aho} \end{bmatrix}_{(141\times 9)\times 1}$$

where α_i is the intercept coefficient for company *i*. β_i is the systematic risk coefficient for company *i*. δ_i and ρ_i are the coefficients for D_1 and D_2, respectively and for company *i*. D_1 is a column vector 141×1 that contains a binary variable equal to 1 on the day of the event and 0 otherwise. D_2 is a column vector of the same dimension, 141×1, with a binary variable that equals 1 each day after the event and 0 otherwise. For example, a significant δ_{suv} means that return for Supervalu was different the day of the outbreak, suggesting possible spillover. On the other hand, a significant δ_{suv} means that Supervalu's rate of return was impacted cumulatively four days after the event.[10] E is the residuals vector.

The results of the multivariate regression (3.10) are shown in Table 3.8. It is important to note that all betas were statistically significant, except for β_{pfgc}. Each of the betas was less than one, which means that all of these companies were less risky than portfolio *m*, as shown in Figure 3.5.

In addition, the only company to report a statistical significant dummy variable, intended to capture spillovers, was Performance Food Group Company (PFGC). This company show a significant coefficient for δ_{pfgc}, with a magnitude of 0.075, as shown in Table (3.10).

However, we were unable to determine if this effect was due to a spillover or to an internal effect. On the same day Sysco's lawsuit was announced, Performance Food Group registered a high increase in their stock due to an internal change in its

[10] The system of equations does not capture earnings and acquisitions

management. These two events, occurring on the same day, present a limitation on the event study approach. The system cannot distinguish were the effect is coming from, just the day on which it occurs.[11]

3.7 CONCLUSIONS

This paper conducts an in depth event study about one of the worst foodborne disease outbreaks in the United States: a hepatitis outbreak in Pennsylvania that affected more than 600 people in 2003.

The results of this paper are consistent with the explanatory power of the simple market model. A significant limitation in this paper is that Prandium was going through a financial crisis when the outbreak occurred. This situation was reflected in the volatility of their stock. Thus, it was impossible to draw results and conclusions on the market model for this firm. However, Sysco and most of the companies showed a significant systematic risk coefficient in this research.

Some interesting results and conclusions emerged in this work. First, there was modest statistical evidence that investors punished the company for being involved in the outbreak. Thus, although it experienced increased volatility after the day of the event, there were no abnormal returns for Sysco's stock.

In addition, there was not significant evidence for spillovers on Sysco's selected clients and competitors. Even the coefficient for Performance Food Group was equal to

[11] Isolating this event with a dummy variable is not feasible since it will be identical to D2, which is contained in the system.

0.075281 and statistical significant, we can not conclude that this is due to a spillover from Sysco's lawsuit. The reason for this is that, on the same day of the event, Performance Food Group announced management changes that generate significant increase in their rate of return. It is not possible to distinguish the market's response between the internal management change and the bad news for its competitors.

We believe that the main contribution of this dissertation is to present a SUR technique to explore for spillovers in the industry and through the supply chain. Finally, this work presents some limitations. The approach used only focuses on the financial markets. Some other studies and approaches may improve the conclusions of this study.

CHAPTER IV

AN ECONOMIC COST MODULE OF A BIO-SECURITY ANIMAL DISEASE RISK SIMULATION

4.1 BACKGROUND

Historically, there have been many major animal disease outbreaks around the world. Some of these outbreaks have cost millions of dollars to control and eradicate. For example, a severe FMD outbreak took place in the United Kingdom in 2001. According to et al. (2003), this outbreak forced authorities and ranchers to slaughter and dispose of more than six million animals. This situation generated huge economic burden on the public and private sector. According to McClaskey et al. (2004), the government expenditures were over ₤ 2.8 billion, plus another ₤ 5 billion was lost in the private sector.

In a 1951 FMD outbreak in Canada, two thousand animals were slaughtered at a cost of $2 million, but due to movement bans and international trade restrictions, the cost increased to $2 billion dollars (Kohnen 2000). Additionally, Kohnen (2000) indicates that an FMD outbreak in Italy in 1993 cost $11 million to control and eradicate, but trade restrictions increased the cost to $120 million.

In their essay, Meltzner et al (2003) point out that several major outbreaks of pandemic influenza have hit the United States. Outbreaks occurred in 1918, 1957 and 1968, causing 20 million human deaths in just the first outbreak. Meltzner et al argue that the possibility of a pandemic of this disease in the United States is very high, especially if avian influenza is imported. Meltzner et al (2003) and the Center for Disease Control and Prevention estimate that the human death rate could be from 89,000 to 207,000; with hospitalizations rising from 314,000 to 734,000; outpatient visits from 18 to 42 million; and additional illnesses from 20 to 47 million. The estimated economic impact of such an outbreak ranges between $71.3 to $166.5 billion dollars.

Additionally, the Classical Swine Fever (CSF) hit Europe severely in 1994, affecting more than 100 German farms and 48 Belgium farms. Only a few years later, in 1997-1998, there was a severe outbreak in The Netherlands where almost 500 farms were infected, and more than 13,000 pig farms had to slaughter animals (Meuwissen 1999).

In addition to the above set of natural, accidental disease animal outbreaks, agriculture faces a new threat: terrorism. In his book, Tweeten (2003) points out that agriculture is an attractive target for terrorists because relatively simple and inexpensive actions can have catastrophic consequences. To reduce potential losses, it is important to explore options to prevent outbreaks and be prepared to respond to natural or terrorism-caused disease outbreaks.

The Department of Homeland Security (DHS) considers agriculture one of the economic sectors most vulnerable to natural or intentional disasters. This concern has led the DHS to fund and establish a Center for Excellence in Foreign Animal and Zoonotic Disease Defense (FAZD) at Texas A&M University. This Center addresses the threats presented by deliberately or accidentally introduced foreign animal and/or zoonotic diseases (fazd.tamu.edu).

This chapter is organized as follows: Section 4.2 presents the objectives and justification of this paper. Section 4.3 reviews previous literature on epidemiologic and economic assessments and identifies the contribution and gaps in previous research. Then, Section 4.4 develops a general conceptual economic model to project the cost impacts and aspects of control strategies against an animal disease outbreak. Subsequently, Section 4.5 presents the case study and describes the hypothetical disease outbreak and the control options investigated in this paper. Then, Section 4.6 discusses the estimation procedures and results of the general conceptual model used to calculate the economic impact of the hypothetical outbreak. Finally, conclusions are presented.

4.2 JUSTIFICATION AND OBJECTIVES

Epidemiological models have been developed to understand how disease outbreaks spread under different circumstances. These studies provide helpful insights into disease mitigation and lay a foundation for management strategies. Often the existing epidemiologic models do not estimate the economic consequences or only partially address them for a particular outbreak; see Berensten et al (1992) and Meltzner et al (2003). This study develops a generic economic module which estimates cost in the face of a simulated animal disease outbreak under different mitigation strategies. This model will subsequently be applied in a case study. The context case study for application involves a hypothetical FMD outbreak in the Panhandle of Texas.

This region was chosen due to its importance in livestock production. According to Lawrence and Otto (2005), Texas is the largest cattle producer in the nation with 15 percent of the US inventory. The Panhandle area has the highest density in cattle production in the state. The area of study considers eight counties: Bailey, Castro, Deaf Smith, Hale, Lamb, Parmer, Randall and Swisher. These counties are shown in Figure 4.1. These counties form a total of 7,942 square miles. There are 92 feedlots, 2,231,300 cattle on feed, 411,019 grazing cattle, and 17,471 land parcels.

4.3 LITERATURE REVIEW

Several studies incorporate epidemiological and economic assessment in their models. For example, Nielen et al (1996) calculated the economic impacts of several different strategies for the 1997-1998 swine fever epidemic in The Netherlands. Using spatial, temporal, and stochastic simulations, they applied economic and cost factors to each of the strategies and found that preventive strategies, such as pre-emptive slaughter, are effective policies in mitigating the economic impacts of the disease.

In the same context, Mewissen et al (1999) developed a model to calculate the economic consequences of the swine fever outbreak for farms, government, and other participants in the pork supply chain. They found that the total cost for The Netherlands outbreak was $2.3 billion dollars.

Meltzner et al (2003) addressed the question of how many vaccinations are needed to reduce the impact of a human influenza outbreak while minimizing costs. They used a mathematical model to calculate the returns to vaccination against this disease. They found that the largest economic returns come from the prevention of deaths, via vaccination, of people who are economically active: younger than 65.

Schoenbaum and Disney (2003) used a disease simulation model to examine hypothetical FMD outbreaks and mitigation strategies in the United States. They found that the choice of strategy depends on the speed of the disease spread and the geographic location of the outbreak. They concluded that slaughtering herds in direct contact with infected premises is the best economic strategy and the fastest way of eradicating the disease. In the same context, Beristein et al (1992) simulated an FMD outbreak in the Dutch cattle and pig herds. They found that slaughter is preferred to routine vaccination. Furthermore, Disney et al (2001), argue that vaccination is less effective because vaccinated animals need to be killed in order to regain access to international markets.

Disney et al (2001) did a cost benefit analysis and found that animal identification is an effective strategy for dealing with disease outbreaks such as FMD. Furthermore, they found that the more vertically integrated the sector, the more benefits will be obtained by implementing traceability as a pre-event strategy. Elbakidze (2004) and Elbakidze and McCarl (2006) analyze ex ante versus ex post strategies in animal disease outbreaks, focusing on the decision making process for the case of an FMD outbreak deliberately caused by terrorist attack. Similar to Nielen (1996), Elbakidze and McCarl (2006) find that for fast spreading diseases, it is more efficient to invest in pre-event strategies rather than rely on post-event actions. Morris et al (2001) evaluate different control policies such as vaccination, slaughter and movement bans for different simulations of the 2001 FMD outbreak in Great Britain. They found that the longer it takes to execute the policies, the faster the disease spreads out and the higher the economic impact.

Bates et al (2001) did a cost-benefit analysis of preemptive slaughter and vaccination as a strategy to mitigate, control, and eradicate an FMD outbreak. They found that vaccination is more cost effective than slaughtering if vaccination does not eliminate future trade.

Jin et al (2005) investigate the optimal level of carcass disposal needed to ensure efficiency in disease management by minimizing the cost of carcass disposal under an FMD outbreak. They found that vaccination plays a very important role in minimizing the total cost of the outbreak since it diminishes the number of slaughter and disposal animals in each period of time.

A general conclusion of the literature is that for fast spreading diseases taking preemptive measures, such as slaughter and vaccination, at the beginning of the supply chain is more cost effective than waiting. This is, ex ante strategies aid to minimize the event cost; such as the loss of animals, the economic impact of the private and public sector and the environmental and health externalities. However, there are a number of variables that make analysis different across regions and countries. Schoenbaun and Disney (2003) point out that the impact of an outbreak depends on trading partners, livestock demography, social reactions, disease-control policies, livestock markets and the general national economy.

4.4 A CONCEPTUAL ECONOMIC MODEL

4.4.1 A general discussion of the model

Ekboir (1999) argues that a disease outbreak generates a total cost that can be divided into three categories: direct costs, extra expenditures in resources, and indirect costs. Thus, this can represented as:

$$TC_s = TDC_s + TER_s + TIC_s \tag{4.1}$$

where TC_s is the total cost of outbreak under mitigation strategy *s*; TDC is the total direct cost which includes market value of lost animals, production losses, welfare slaughter costs and consumer surplus losses; TER is the summation of all extra expenditures to mitigate the disease, such as surveillance implementation, slaughter costs, quarantine implementation, and vaccination costs; TIC is the summation of all indirect costs, including loss of employment and indirect production losses. Different mitigation strategies *s* are compared during the hypothetical outbreak. The best strategy is the one that generates the lowest total cost (TC). This general model is deterministic and static.

4.4.1.1 Interaction of the epidemiologic model and the economic module

To calculate (4.1), output data from an epidemiologic model needs to be incorporated. An epidemiologic model provides information about the behavior of the disease and quantifies it in terms of the numbers of animals which become sick. In addition, the epidemiologic model uses various herd attributes, such as contact rates, location, operation type, as well as characteristics of environment in order to project the spread of the disease. The epidemiologic model assigns a particular identification number (*id*), a herd type (*ht*); such as, feedlot, dairy, swine, etc. and the number of animals (*NAN*) in the herd.[12] See Table 4.1.

[12] Some calculations may be needed in order to obtain the distribution of animal types due to composition; such as, bulls, cows, calves, etc.

As a result of disease spread simulation, the epidemiologic model assigns herd *status* and applies different *control options* to each herd. The status describes the health condition of the herd, such as infected, immune, dead and latent; the control variables refer to the categorical condition assigned by the authorities, such as vaccination, surveillance, quarantine, etc.

All states are mutually exclusive from one another. This is, each farm can only be in one status at a time, but different combinations of control options can be applied to each farm. For example, a farm can be either infected or immune, but can be under surveillance, vaccination and quarantine at the same time.

4.4.2 Direct costs definitions

The first component of equation (4.1) is the direct cost (DC_s) which arises from animal losses under the outbreak. The total direct cost (*TDC*) of the outbreak under strategy *s* is equal to:

$$TDC_s = TMVL_s + TFI_s + TWSC_s + TCS_s \tag{4.2}$$

where *TMVL* is the market value of lost animals, *TFI* is the foregone income of farms, *TWSC* is the welfare slaughter and movement restriction losses, and *TCS* represents consumer surplus loss, all under strategy s.

4.4.2.1 Total market value of lost animals (TMVL)

Under eradication guidelines of zoonotic diseases (USDA 2004), infected and latent farms plus other discretional selected herds, depending on the implemented strategy (i.e. infected slaughter, ring slaughter, etc.), have to be destroyed. This cost is equal to the market value of loss of animals due to depopulation. Thus, *TMVL* is equal to the total number of slaughtered animals according to their type and market price prior to the outbreak.

In order to calculate the *TMVL,* we account for the number of animals (*NAN*) in the herd (id) that is of a type (ht). In order to find this value, we need to convert the total number of animals slaughtered into the number slaughtered by type of animal. This cost can be expressed in the following equation:

$$TMVL_s = \sum_{id}\sum_{ht}\sum_{at}\sum_{status} NAN_{id} AHT_{id,ht} LH_{id,status,s} Comp_{ht,at} V_{at} \tag{4.3}$$

where:

NAN_{id} = the number of animals in the herd (id)

$AHT_{id,ht}$ = 0 if herd (id) is not of a type *ht*

1 if herd (id) is of a type *ht*

$LH_{id,status,s}$ = 1 if herd (id) is latent, infected, immune, or dead under strategy s

0 otherwise

The third subscript *s* indicates that LH varies depending on the strategy *s* used.

$Comp_{ht,at}$ = Proportion of animal of type (*at*) in herd type (*ht*)

V_{at} = Value per animal of type (*at*)

The first four right hand side variables in equation (4.3) indicate the number and type of animals slaughtered in herd (id). Summing these four terms and multiplying by the market price of the animal (*at*) before the outbreak (V) and sum over (id) will result in the Total Market Value Lost (4.3).

4.4.2.2 Total foregone income (TFI)

There is a period of time when farms do not produce anything due to livestock depopulation. This production inactivity lasts until the reintroduction of new animals. According to mitigation and eradication guidelines by the USDA (2004), an infected farm cannot return to production until 60 days after cleaning and disinfection.

This cost is equal to the sum of the farm's daily incomes for the period during the farms' production inactivity. This cost will vary depending on the season that the farm is inactive; livestock farmers have different cash flows during the year due to breeding, replacement and selling being seasonal.

This cost is equal to the forecast average income of the farm during the farm's inactivity and can be expressed as:

$$TFI_s = \sum_{id} \sum_{ht} \sum_{hs} \sum_{status} LH_{id,status} AHT_{id,ht} HS_{id,hs} Income_{ht,hs} * time_{id} \qquad (4.4)$$

where

$LH_{id,status,s} =$ 1 if status of the herd (id) indicates the status = latent, infected, dead or immune according to strategy s

0 otherwise

$AHT_{id,ht} =$ 1 if herd (id) is of a type *ht*

0 otherwise

$HS_{id,hs} =$ 1 if herd (id) is of herd size (hs) (i.e. small, medium, large)

0 otherwise

$Income_{ht,hs} =$ loss per day per herd type (*ht*) and size (hs)

$Time_{id,s} =$ number of days that the farm (*id*) was inactive; from the day that animals were slaughtered to the day that production is reinitiated. In some cases the time of inactivity may vary depending on the strategy.

4.4.2.3 Welfare slaughter costs

During an outbreak, movement restrictions are implemented in the form of a quarantine zone in order to stop the spread of the disease. When an area is under quarantine, feed and veterinary supplies may not reach farms. Lacking supplies will have an economic impact on the farms. First, if feed does not arrive at a farm on time, animals may not experience expected weight gain or may even lose weight. Also, movement restrictions over time may affect the health of the animals, and some may have to be slaughtered as a consequence. Moreover, farmers will incur costs if there are animals in stock that were ready to be taken to the slaughter house, but because of movement restrictions, farmers need to keep feeding for longer periods of time. This situation may be extended to the point that it is cheaper for the farmer to slaughter the animal than continue feeding the animal for a long period of time without being able to sell it due to movement restrictions. All of these effects are called welfare slaughter.

Welfare slaughter costs can be expressed as

$$
\begin{aligned}
TWSC_s = & \sum_{id}\sum_{ht}\sum_{at}\beta_{ht}(time_s)NAN_{id}AHT_{id,ht}Q_{id,s}Comp_{ht,at}V_{at} + \\
& \sum_{id}\sum_{ht}\sum_{at}NAN_{id}AHT_{id,ht}Comp_{ht,at}WL_{at,s}(time_s)VW_{at}Q_{id,s} + \\
& \sum_{id}\sum_{ht}\sum_{at}\alpha_{at}NAN_{id}AHT_{id,ht}Comp_{ht,at}Q_{id,s}VF_{at}time_s
\end{aligned}
\tag{4.5}
$$

where

$\beta_{ht}(time_s)$ = proportion of animals in herd type (ht) that are killed; this is a function of time that the animals are in quarantine

NAN_{id} = the number of animals in herd (id)

$AHT_{id,ht}$ = 0 if herd (id) is not of a type *ht*

1 if herd (id) is of a type *ht*

$Q_{id,s}$ = 0 the herd (id) is not quarantined

1 herd (id) is quarantined

$LH_{id,status,s}$ = 0 if herd (id) is not of status

1 if herd (id) is of status

$Comp_{ht,at}$ = Proportion of animal of type (*at*) in herd type (*ht*)

V_{at} = Value per animal of type (*at*)

$WL_{at}(time_s)$ = total weight loss of animals over time

VW_{at} = value of the weight for animal type (at)

α_{at} = percentage of animals ready to be marketed

VF_{at} = value of the feed use for animal type (at) per day

$Time_s$ = number of days that the herd (id) was cut in transit under quarantine restrictions under strategy s

4.4.2.4 Loss of consumer surplus

Loss of consumer surplus is the last component of the direct cost equation in (4.2) and refers to the economic impact of the outbreak on consumers. One way of analyzing this is through welfare analysis. Consumers' surplus will be affected due to changes in supply and demand that will affect market prices and quantities.

Supply changes are due to the loss of animals along with the movement restrictions and quarantine and trade restrictions. On the other hand, demand changes are a result of changes in preferences. That is, consumers may change their consumption preferences to other types of meat which have not been affected by disease. For example, avian influenza outbreaks are currently causing consumers to switch from chicken to beef consumption in areas where this disease has appeared.

The economic impact on consumers can be estimated by measuring the changes in consumers' surplus after the outbreak. An illustration of this is portrayed in Figure 4.2 and Figure 4.3. There are three scenarios explored here: in the first scenario only production is affected by the outbreak; in the second scenario both preferences and production change; the third scenario captures the welfare effects due to trade restrictions.

i. Consumers' surplus due to production losses

Figure 4.2 assumes that before the outbreak event, the equilibrium is where supply (S_0) equals demand (D_0) with market price (P_0) and quantity market (Q_0). This generates a consumers' surplus area of ($A,0,P_0$) and a producers' surplus area of ($C,0,P_0$). Suppose that after the outbreak the supply shifts to (S_1) and consumer preferences do not change. This generates new consumers' and producers' surpluses equal to ($A,1,P_1$) and ($B,1,P_1$), respectively. Thus the loss of consumer surplus is the area (P_1, 1, 0, P_0) is transferred directly as producers' surplus gains. This is evidently due to the reduction of quantity and price increase.

ii. Welfare effects due to production and preference changes

A different scenario is presented in Figure 4.3 where not only supply changes, but demand as well due to change in preferences. In addition, in this case we explore more elastic demands. In this scenario, we assume that the market is at equilibrium before the disease outbreak, so supply (S_0) equals demand (D_0), with quantity (Q_0) and market price (P_0). At this stage, the consumers' surplus (CS_0) is reflected by the triangular area (A, 0, P_0). If we assume that preferences change as well as the supply, the new equilibrium after the outbreak is where (S_1) equals (D_1) with a market price (P_1) and quantity (Q_1). This generates a consumers' surplus loss of ($A,0,P_0$) minus ($B,1,P_1$).

iii. Consumer effects due to trade restrictions

A domestic market labeled as a disease free country will allow producers to have access to international markets, which are willing to pay a premium for disease free products. This situation may push domestic prices up as illustrated in Figure 4.4.

Under a closed economy, the market price and quantity will be (P^*) and (Q^*), respectively, as shown in Figure 4.4. Under this scenario, the consumer surplus is

(A,0,P*). However, if the country is disease free, the international markets may pay a price with a premium, say (P^E), which is higher than the domestic (P*), thus producers will produce (Q^{ES}) and domestic consumers will consume only (Q^{ED}), generating an excess supply that will be exported. However, under an outbreak scenario, the world prices will immediately drop, say to (P^0). This will cause an excess in demand, since at that price consumers are willing to buy (Q^{OD}), but suppliers are willing to supply (Q^{OS}). The excess in supply will be equal to (Q^{OD}) minus (Q^{OS}). The gain in consumer surplus due to the drop in price is represented by the area (1,2,6,4).

4.4.3 Extra expenditures

Extra expenditure costs are the second component of the total cost equation in (4.1). These costs consider all the extra private and public resources spent to mitigate, control, and eradicate the disease. The total extra expenditure cost (TER) of the outbreak under strategy *s* can be calculated using the following equation:

$$TER_s = TSLC_s + TSURC_s + TCQI_s + TVC_s \tag{4.6}$$

where (TSLC) is the total slaughter costs, (*TSURC*) represents the total surveillance costs, (TCQI) calculates the total cost of quarantine implementation, and (*TVC*) is the vaccination costs.

4.4.3.1 Total slaughter costs (TSLC)

Total Slaughter Costs (TSLS) capture the expenditures of depopulating the infected, latent, dangerous contacts, farms within a ring, and the animals slaughtered under quarantine. The cost of depopulating these premises consists of the euthanasia

(*Eut*) and carcass disposal cost (*CD*) per animal, the cost of appraisal (*APC*), and the cost of cleaning and disinfecting the premise (*CCD*). The last two costs are based on the herd size (hs): small, medium and large.

The cost of appraisal (APC) per herd is the cost of sending experts to the infected and latent premises to estimate market losses for the farmers. The cost of euthanasia is the cost of slaughtering animals. The carcass disposal cost refers to the expenses of discarding the slaughtered animals. The final cost category is the expense of cleaning and disinfecting the premise, so the farm is free from viruses.

The computation of Total Slaughter Costs (TSLC) is divided into three parts. First, we account for the costs of slaughtering the animals that were infected, latent or immune. In order to do this, we account for the animals in herd (*id*) based on herd type (*ht*) and get the number of animals (*NAN*) according to their type (*at*) that will be slaughtered due to a particular status (*status*) in (*LH*). To calculate the euthanasia and carcass disposal cost per animal, we multiply the total number of animals in the herd (id) times the euthanasia (*eut*) and carcass disposal (CD) cost per animal. Using a similar approach, we account for the cost of slaughtering the animals that were under quarantine.

The third part of the equation calculates the appraisal (*APC*) and cleaning and disinfection (*CCD*) costs, which are a function of the herd size (hs) and type (ht).

$$TSLC_s = \sum_{id}\sum_{ht}\sum_{at}\sum_{status} NAN_{id} AHT_{id,ht} Comp_{ht,at} LH_{id,status,s}(eut + CD) +$$
$$\sum_{id}\sum_{ht}\sum_{at} \beta_{ht}(time_s) Q_{id} NAN_{id} AHT_{id,ht} Comp_{ht,at}(eut + CD) + \quad (4.7)$$
$$\sum_{id}\sum_{hs}\sum_{status}(APC_{hs} + CCD_{hs}) LH_{id,status,s}$$

4.4.3.2 Total surveillance cost (TSURC)

Total Surveillance Cost (TSURC): According to USDA (1991) regulations, a farm in direct contact or located within a specified geographic area near the outbreak will be labeled a farm under surveillance. These farms will receive visits of inspection and will be tested. Usually, this routine will continue for several weeks after the last case is found and government takes care of the costs. These visits will include a sample test per herd to check for the virus. The surveillance considers two types of costs: the cost of the testing (*CT*) each herd and the cost of visiting (*CV*) the farms under surveillance. In order to compute this cost, we account for the number of visits (*NV*) conducted in a herd (*id*) under surveillance (HS) times the cost of the visit plus the cost of each test (*CT*), which depend on the herd size (*hs*). This is expressed in the equation:

$$TSURC_s = \sum_{id}\sum_{hs} HS_{id,hs} NV_{id} * (CT_{hs} + CV_{hs}) \quad (4.8)$$

where

$HS_{id,hs}$ = 1 if herd (id) of size (hs) is under surveillance

0 otherwise

4.4.3.3 Quarantine and security implementation cost (TCQI).

According to the Quarantine and Movement control (USDA 2004), the purpose of quarantine is to prevent pathogens from spreading. When a premise is declared infected, all roads and access points that conduct to that premise must be shut down. This action is supervised by State and or Federal authorities, depending on the case. Implementing movement restrictions and security mechanisms will generate costs for the resources used to achieve this control policy. This can be represented in the following equation.

$$TCQI_s = NP_s * w + Trans + E + OM \tag{4.9}$$

where

NP_s	=	the number of personnel enforcing the quarantine
w	=	wages
$Trans$	=	Transportation costs
E	=	Equipment and supplies
OM	=	Other materials such as barriers, warning signs, etc

where the last three costs of equation (4.9) are fixed and do not depend on the strategy s used.

4.4.3.4 Vaccination cost (TV)

Vaccination is a strategy to contain the disease quickly; it isolates the infected areas from non-infected areas and reduces slaughter volumes. This type of expenditure is usually paid by the farmer and/or the government, depending on the situation.

Total vaccination cost (*TVC*) has two main components: a variable and fixed cost. The variable cost is the cost per animal vaccination. The fixed cost is the cost of sending personal to provide the shots. These two costs can be expressed in the following equation:

$$TVC_s = \sum_{id} NA_{id} V_{id,s} CV + \sum_{id} \sum_{hs} V_{id,s} HS_{id,hs} FCV_{hs} \qquad (4.10)$$

where

$V_{id,s}$ = 0 if herd id is not vaccinated

1 if herd id is vaccinated under strategy s

CV = Cost of vaccination per animal

$HS_{id,hs}$ = 1 if herd (id) is of herd size (hs); i.e. small, medium, large

0 otherwise

FCV_{hs} = Fixed cost of vaccinating per herd size (hs)

4.4.4 Indirect costs

Indirect costs are created by the outbreak on businesses linked to the affected industry. These include the economic loss of employment (*LE*) and economic losses of firms linked to the affected industry (*IPL*).[13]

$$TIC_s = LE_s + IPL_s \qquad (4.11)$$

[13] The indirect costs can also include some externalities such as damages to the environment and health. These types of costs are topics for future research.

4.4.4.1 Loss of employment (LE)

As a result of stopping production, farm workers will be unemployed. We account for this as follows:

$$LE_s = \sum_{id}\sum_{ht}\sum_{hs} \theta_{id} NE_{ht,hs} AHT_{id,ht} HS_{id,hs} LH_{id,status} w * time_s \qquad (4.12)$$

where

θ = percentage of laid off people in herd (id) out of total workers

$NE_{ht,hs}$ = the number of employees in herd type (ht) of herd size (hs)

$AHT_{id,ht}$ = 1 if herd (id) is of a type *ht*

0 otherwise

$HS_{id,hs}$ = 1 if herd (id) is of the size (i.e. small, medium or large)

0 otherwise

$LH_{id,status}$ = 1 if herd (id) is in status (i.e. infected, dead, immune)

0 otherwise

w = wage per employer in (id) during the time of inactivity

$time_s$ = time of inactivity under strategy s

4.4.4.2 Indirect production loss (IPL)

Due to eradication guidelines, the affected farms will depopulate and halt production for 60 days after cleaning and disinfection. This inactivity will affect businesses (*b*) that are linked to the affected farms, such as feeders and other input suppliers. The Indirect Production Loss (ILP) is equal to:

$$TIPL_s = \sum_{b}^{B} Income_b * time_s \tag{4.13}$$

where $Income_b$ is the daily foregone income of businesses (b) that is linked to the affected farms and *time* is the number of days of inactivity.

4.5 THE CASE STUDY

The case study presented in this paper uses the general conceptual economic model developed in Section 4.4 to predict the cost of a hypothetical Foot and Mouth disease outbreak in the Panhandle region of Texas. Seven different types of farms in this region are analyzed: (1) large beef cattle operations (more than 10 heads in inventory), (2) dairy, (3) sheep, (4) swine, (5) sheep and swine, (6) small beef operations (i.e. cattle in backyards, less than 10 heads) and (7) feedlots.

The economic cost module captures two main facets during this outbreak: first, the cost of the disease behavior, and, second, the cost of mitigating the disease.

In the hypothetical outbreak, the cost of the disease behavior begins when one herd is randomly infected; then, it continues spreading among other herds. The cost of mitigation begins when authorities start applying different control options to mitigate the disease.

Several control options are considered in this case study. All of them correspond with the USDA guidelines.

The first control option to be applied when a herd is suspected or confirmed to have the disease is to quarantine it, according to the USDA (2003) guidelines.

Quarantine refers to applying movement restrictions to those premises infected or suspected to be infected with the disease. Quarantine mitigates and seeks to prevent the spread of disease.

After a herd is under quarantine, some other control variables may apply depending on the herd status. For example, a quarantined herd could be vaccinated or slaughtered or turn into a herd under surveillance.

Vaccination is a control option that will delay the spread of the disease to other animals. It will also buy time to slaughter and dispose of animals at different points in time, rather than doing it all at once. This epidemiological case considers two different vaccination strategies: ring vaccination and targeted vaccination. The first strategy vaccinates within a geographical area and the second targets specific herds.

Another control option used is surveillance, which refers to sending professional people to visit farms within 15 kilometers of the outbreak, in accordance with USDA guidelines (1991). The surveillance costs include testing and professional visits. These visits continue for 30 days after the last case of infection (see Table 4.2).

The fourth control option is to slaughter the animals that are in a particular status; such as latent, immune, or infected. Slaughtering can also be applied to herds that due to their proximity have the potential to be infected.

This case study uses different control options to form strategies to mitigate the disease. There are five different control strategies, and they are shown in Table 4.3.

As can be observed in Table 4.3, each strategy is a combination of different control options to herds under a particular status. For example, Strategy 2 indicates to quarantine, surveillance, and slaughter all herds under the status “latent, immune, or infected” plus implementing the control option to slaughter dangerous contact herds.

The infected herds are defined as herds that have animals shedding the virus and may transfer it to other animals or herds. Dangerous contacts are herds that have not been confirmed to have the virus but have the potential to get it due to their proximity or potential contact with infected herds. Finally, contiguous herds are herds that are located close to the infected herds.

These five strategies generate different hypothetical epidemiological outputs, and the summary statistics are presented in Table 4.4.

The simulation model used here incorporates some movement restrictions after the detection of the outbreak; herds affected by movement restrictions are labeled as herds in quarantine and are shown in Table 4.4. These restrictions follow the USDA and Texas Animal Health Commission guidelines, which request for an immediate end to movement after the first case of FMD is diagnosed.

Additionally, the surveillance implementation follows the guidelines of the USDA Quarantine and Movement Control (2003) which states that a radius of 3 kilometers must be flagged for surveillance from the location of the herd detected with FMD. The surveillance requires different numbers of visits, which are reported in the output results of the epidemiological model. Infected areas will be vaccinated at the discretion of Federal authorities. Vaccination is a strategy to create barriers between infected areas and disease free regions. Finally, all infected and latent herds will be slaughtered.

According to the team leaders of this model, one of the main highlights that this method offers is that it captures the spread of disease due to cattle movement across the region as well as through direct and indirect contacts. This is a stochastic susceptible-infected-recovered (SIR) model, which allows using different types of GIS (Geographic Information System) data; such as polygons or simple points. This epidemic model is orthogonal and the simulation can be initiated at any location(s), allowing to capture the epidemic progression and to trace back the dynamics of the spread.

4.6 DATA

Data comes from different data bases, literature and in some cases from personal interviews with experts. In addition, some data needed to be calculated in order to complete the economic model. Two types of data are entered as inputs in the economic model: epidemiologic and economic data.

4.6.1 Epidemiologic data

The epidemiologic data comes from a model developed by Garner (1994), which is being adjusted and modified by The National Center for Foreign Animal and Zoonotic Disease Defense (FAZD) at Texas A&M University. [14] Some of the epidemiologic inputs used in this project can be found in Ward (2006). As described in Section 4.4.2, some calculations and adjustments needed to be done in order to convert the epidemiologic output to an input for the economic model. These calculations are

[14] Linda Highfield and Dr. Ward are leading this project.

explained in the next section along with the variables and parameters used in the calculation of the economic model.

4.6.2 The economic data

4.6.2.1 Market value per animal (V_{at})

In order to obtain the market value per animal (V_{at}) some calculations need to be done. The epidemiologic model does not report the number of each type of animal in each herd, but only the total number of animals (NAN) in each herd. To correct for this, the number of animals (NAN) in herd (id) of type (ht) was decomposed into types of animals using a matrix called animal composition (Comp). This matrix is shown in Table 4.5 and contains the percentages of animal types in each type of herd. Each column in the matrix indicates the percent of animal types corresponding to the herd type. If the value is 0.00% that means the animal type does not exist in that herd type. There are a total of nineteen different animal types in the study for all the herd types. Some herds have more animal types than others, for example, grazing farms have six types of animals and the mix farms have eight. Obtaining the data on composition had several limitations, especially because in reality the animal composition varies from farm to farm. For example, the composition of grazing farms varies significantly from one to another.[15]

[15] We are grateful to Doug Tolleson at the FAZD Center for providing this valuable information. This data is a discretionary estimate.

In order to obtain the number of animals by type, a multiplication of the scalar (NAN) times the corresponding column (by herd type) of the matrix (Comp) is carried out.

Market prices for each animal type come from the National Agricultural Statistics Services (NASS) Agricultural Statistics Board, produced by the USDA. This document was released on January 31, 2006. These prices are expressed in hundred pounds (cwt) and are shown in Table 4.5.

Because animal prices are expressed in (cwt), in order to obtain the value per animal (V_{at}), we assign an average weight to each animal and multiply it by its price in (cwt). These weights are shown in Table 4.6 and are obtained from the Agricultural Marketing Service, USDA. Then, with all the weights and the values expressed in the same units, the price for each animal type (V_{at}) is calculated as shown in the third column of Table 4.6.

4.6.2.2 Welfare and slaughter costs

In order to determine the number of animals that die due to quarantine and movement restrictions, we impose a β equal to 5 percent. This indicates that five percent of the animals that were under the status of quarantine died.[16] The reason for this is that evidence shows that during the FMD outbreak in the UK, 30 percent of all

[16] This assumption may be strong, since the number of animals in welfare slaughter may vary depending on their herd and animal type and even from other circumstances; such as the weather. This is, if the weather allows for good grass, some types of animals, such as cattle may resist dying from movement controls.

animals slaughtered were due to welfare. That is, if we let β=.05, this will give us an average of 30 percent of all animals slaughtered due to wealfare.

The last two parts of the welfare equation (4.5) were not calculated due to lack of data. We do not have any data or evidence of the loss of weight of animals and the value of animals not marketed due to quarantine.

4.6.2.3 Slaughter, surveillance and vaccination costs

Schoenbaum and Disney (2003) estimated costs are used in order to compute the slaughter, surveillance, and vaccination costs. The cost of slaughter and surveillance varies depending on the herd size (hs). There are just three sizes in this study: small (0 to 99 animals), medium (100 to 500 animals) and large (more than 500 animals). It is assumed that size determination is the same across herd types. That is, a hog farm with 99 animals and a dairy with the same number of animals are both considered small farms. Another assumption is that the cost of slaughter and surveillance is the same regardless of herd type. These costs are shown in Table 4.2 and 4.7.

The cost of vaccination has two components: a variable and a fixed cost. For each herd that is vaccinated, a fixed cost is incurred regardless of the number of animals vaccinated. In addition, a variable cost comprised of the expense of vaccinating each animal is added.

4.6.2.4 Employment

The employment data is calculated using information from the National Cattlemen's Beef Association. There are approximately forty-thousand jobs related to agriculture in the Panhandle area. In order to estimate the number of layoffs due to an outbreak, we assume 25 percent of the total employment in the area will be subjected to layoffs. This is, we impose the parameter $\theta = 0.25$. This is a strong assumption, since there is no previous information on how many people would lose their jobs or for how long under an FMD outbreak in the Panhandle region of Texas.

4.6.2.5 Cost of quarantine implementation

In order to calculate the quarantine implementation, as described by equation (4.9) we use previous documentation by McCauley et al (1979). In their work, they estimate the cost for a hypothetical case related to an FMD outbreak in Minnesota. We use this last case to calculate the cost of quarantine in Texas. They assume that 28 roads are closed for the duration of the quarantine. They use 52 one-man stations and 6 two-man base stations to quarantine the area. This is, to quarantine an area due to an FMD outbreak, they use 64 people. Since their costs are expressed in 1979 prices, we adjust them for inflation. Assuming the yearly costs of quarantine for the state of Texas are the same as Minnesota's, we have:

Salary of personnel	\$6,534,869
Transportation	\$94,092
Warning signs	\$65,527
Equipment	\$328,479
Barriers	\$93447
Total Quarantine Cost:	\$7,119,416 per year

Thus, if the outbreak lasts 90 days, and, assuming the quarantine has the same duration, the cost for implementing a quarantine is \$1,779,854.

4.6.2.6 Income per farm

In order to calculate the Income Production Loss in equation (4.13) we use data obtained from the Agricultural Income and Finance Outlook (USDA 2005). This data is expressed as a national average per farm type, regardless of farm size. Although this assumption might seem strong, income per farm varies significantly, and there might be cases where a medium beef farm is making more income than large farms of the same type.

4.7 APPLICATION OF THE ECONOMIC MODEL AND RESULTS

4.7.1 The case of a hypothetical outbreak of FMD in the Texas Panhandle

In order to calculate the economic cost for a hypothetical outbreak of an FMD outbreak in the Texas Panhandle, the methodology described in section 4.3 is used. All computations were performed in GAMS.

The total cost of the outbreak begins by calculating each component of equation (4.1) for each of the five independent strategies. The summary of results is shown in Table 4.8.

As shown in Table 4.8, the lowest total cost of the outbreak is generated under strategy one, and the highest cost is generated when strategy four is applied.

The reason that strategy one generates the lowest cost is because this contains few control options: only surveillance, quarantine, and slaughter if infected. This strategy is not as aggressive as the rest of the strategies, which additionally implement vaccination and/or the slaughter of dangerous contacts and/or contiguous herds.

In contrast, strategy four contains more control options, including ring vaccination, in addition to the control options used in strategy one. Moreover, the results of equation (4.1) show that total direct cost is the most significant component of total costs. It represents more than 95 percent of the total costs.

However, the magnitudes of the components of total direct cost vary depending on the strategy used. For example, under strategy one, total welfare slaughter is almost four times larger than the market value of the animals lost. On the other hand, under strategy four this relationship is reversed, with the market value of lost animals seven times larger than welfare slaughter costs. The reason for this is that when vaccination is applied, the quarantine buffer is much wider, increasing the costs for welfare slaughter.

The components of the direct cost vary depending on the control options used. For example, even though strategy one presents the lowest total direct cost and total cost, it contains the highest welfare slaughter cost. On the other hand, strategy four presents the highest total direct cost but the smallest welfare cost. The reason for this is that strategy four compensates with the control option of vaccination, so the quarantine buffer is small.

In the same context, strategies four and five present the highest foregone income but the smallest welfare slaughter. These results show that there is a tradeoff between vaccination, slaughter, and quarantine. When vaccination is applied, the quarantine buffer is small, but the number of slaughtered herds will increase.

For the total extra expenditure resources, strategies four and five present the highest expenditures. This occurs because when herds are vaccinated, more herds will go to slaughter, which generates a cost.

For the calculation of indirect cost, we face several limitations. Even if data was available, this changes depending on many variables. Some of the indirect cost effects even depend on psychological variables.

4.8 CONCLUSIONS

Estimating the economic impact of a disease outbreak assists in laying the foundation for better policy design and implementation in case of an unexpected disease outbreak. The current literature review shows that most of the existing studies focus on the epidemiologic side. They are usually an extension of the epidemiologic models. Section 4.4 in this chapter tries to fill out that gap by presenting a general economic conceptual model to be used under different situations and using an epidemiologic model as a source of inputs.

Within an economist mindset, the goal should not be only to calculate purely the economic impact of the disease, but to also explore different alternatives and strategies to minimize costs.

The main limitation we face in applying the general economic model to the case study is data availability in different areas. For example, there is no detailed data on welfare slaughter; thus we must impose assumptions, whose results can vary significantly when relaxed.

However, the results presented in this paper suggest that the best policy is to slaughter only the infected, latent and immune herds. Among the five strategies used in this research, the least preferred is the one that slaughters the infected, latent and immune herd slaughter in addition to ring vaccination. It is important to mention that this research carries some limitations. For example, different sizes of outbreaks need to be studied in order to derive more robust conclusions about economic efficiency of each strategy. For the particular case of this research, a small outbreak indicates that vaccination is not economically efficient but that might not be the case if the outbreak is larger. Moreover, this research would also be more robust if uncertainty were factored in.

CHAPTER V

CONCLUSIONS

This dissertation studies different aspects of the supply chain in diverse markets under different conditions. The first paper (Chapter II) analyzes the behavior of farm to retail price transmission for the milk industry in selected cities of the United States. The Houck approach and the von Cramon-Taubadel and Loy Error Correction Model approach were used. The results for the farm to retail price transmission parallels what the literature has documented for other markets: there is asymmetric transmission for each of the seven cities analyzed. In addition, presenting the segmented elasticities of price transmission is important. Few previous related works have provided the estimates of these elasticities. The segmentation provides vital information about the relation between retail and farm prices and the structure of the market. They measure the percentage change in retail price of a commodity due to a one percent change in farm price.

Another important result is that the Houck and the Error Correction Model were compared statistically, and there is little evidence that the latter is superior. The main difference between these approaches is the speed of adjustment. Under the ECM, changes in retail prices adjust faster to positive changes in farm price than to negative changes in farm prices. Under the ECM, the retail prices adjust very slowly to negative changes in farm price. However, the Houck results do not show a distinction in the speed of adjustment. The computed elasticities of price transmission for rising farm prices are generally larger than the corresponding elasticities associated with falling farm prices calculated under both approaches, Houck and ECM. Finally, the short-run elasticities were smaller in magnitude than the ones previously reported in the literature.

The second paper (Chapter III) conducts an event study related to one of the worst foodborne disease outbreaks in the United States food industry. The incident refers to a hepatitis outbreak that sickened more than 600 people. There were two main companies involved: Prandium and Sysco.

Event study methodology was the main tool to evaluate how the outbreak affected the value of the firms. Moreover, this model was extended to study how the event affected the rate of returns and risk of other companies positioned in the same supply chain and industry.

Applying the market model to investigate Prandium had some limitations, mainly because this company filed for bankruptcy a few weeks before the outbreak.

However, the augmented market model for Sysco generated interesting results. The systematic risk coefficient was less than one and significant. However, there was no evidence of abnormal returns, although the GARCH (1,1) model suggested evidence that the returns on stock were more volatile after the event.

Finally, we augmented the market model to explore for spillovers in the industry and through the supply chain due to the hepatitis outbreak. We were unable to find any evidence for spillovers. The only company to have a statistical significant coefficient in the system was Performance Food Group Company. However, we were unable to determine if this effect was due to a spillover or an internal event of this company, since both events coincided on the same day. The rest of the companies did not present any spillover effects.

However, even if there was no clear evidence for spillovers in this particular case, the SUR technique is a versatile tool to test for spillovers in the industry and thought the supply chain.

The third paper (Chapter III) developed a general economic model that accounts for the potential economic impact of a disease outbreak. Then, the model was presented for the hypothetical case of an FMD outbreak in the Panhandle of Texas. Five different strategies were evaluated.

The results show that for this type of outbreak, lasting only 90 days, the best strategy is only to slaughter the infected herds. It seems that any other type of strategy would not be as efficient as the first one. However, these results could change if, for example, the length of the outbreak is larger in size and longer in time.

REFERENCES

Aguiar, D. and Santana, J.A. "Asymmetry in Farm to Retail Price Transmission: Evidence for Brazil." *Agribusiness*, 2002, *18*, pp. 37-48.

Andersen, T.; Bollerslev, T.; Diebold, F. and Vega, C. "Microeffects of Macro Announcements:Real Time Price Discovery in Foreign Exchange." *The American Economic Review*, 2003, *93* (1), pp. 38-62.

Bailey D. and Brorsen, B.W. "Price Asymmetry in Spatial Fed Cattle Markets." *Western Journal of Agricultural Economics*, 1989, *14*, 246-252.

Bailey, K.W. "Impact of the Northeast Interstate Dairy Compact on Consumer Prices for Fluid Milk." *Review of Agricultural Economics*, 2003, *25*, pp. 108-122.

Balke, N.S. and Fomby, T.B. "Threshold Cointegration." *International Economic Review*, 1997, *38*, 627-645.

Bates, T.; Carpenter, T. and Thurmond, M., "Benefit-Cost Analysis of Vaccination and Preemptive Slaughter as a Means of Eradicating Foot and Mouth Disease." *American Journal of Veterinary Research*, 2003, *64* (7), pp. 805-812.

Beristein, P.B.; Dijkhuizen, A.A. and Oskam, A.J. "A Dynamic Model for Cost-Benefit Analyses of Foot-and-Mouth Disease Control Strategies." *Preventive Veterinary Medicine*, 1992, *12*, pp. 229-243**.**

Bernard, J.C. and Willett, L.S. "Asymmetric Price Relationship in the U.S. Broiler Industry." *Journal of Agricultural and Applied Economics*, 1996, *28*, pp. 279-289.

Binder, J. "The Event Study Methodology." *Review of Quatitative Finance and Accounting*, 1998, *11*, pp. 111-137

Bollerslev, T. "Generalized Autoregressive Conditional Heteroskedasticity." *Journal of Econometrics*, 1986, *31*, pp. 307–327.

Borenstein, S.; Cameron, A.C. and Gilbert, R. "Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes?." *The Quarterly Journal of Economics*, 1997, *112*, pp. 305-339.

Boyd, S.M. and Brorsen, B.W. "Price Asymmetry in U.S. Pork Marketing Channel." *North Central Journal of Agricultural Economics*, 1988, *10*, pp. 103-110.

Brown S. and Warner, J. "Using Daily Stock Returns: The Case of Event Studies." *Journal of Financial Economics*, 1985, *14* (1), pp. 3-31.

Brown, S. and Weinstein, M. “Derived Factors in Event Studies.” *Journal of Financial Economics*, 1985, *14* (3), pp. 491-495.

Cable, J. and Holland, K. “Regression vs. Non-Regression Models of Normal Returns: Implications for Event Studies.” *Economic Letters*, 1999, *64*, pp. 81-85

Chugh, L.; Hanemann, M. and Mahaparta, S. “Pollution Control Regulations” *Journal of Economic Studies*, 1978, *5* (1), pp 64-70.

Corhay, A. and Tournai, R. “Conditional Heteroskedasticity Adjusted Market Model and an Event Study.” *The Quarterly Review of Economics and Finance*, 1996, *36* (4), pp. 529-538.

da Graca, T. “Stock Market Performance of Winners in Privatization Auctions: A New Event Study Methodology.” Unpublished Ph.D. Dissertation, Department of Economics, Cornell University, 2002.

Disney W.T.; Green, J.W.; Forsythe, K.W.; Wiemers, J.F. and Weber, S. “Benefit-Cost Analysis of Animal Identification for Disease Prevention and Control.” *Scientific and Technical Review International Office of Epizootics*, 2001, *20*, pp. 385-405.

Dolley, J.C. “Characteristics and Procedure of Common Stock Split-Ups.” *Harvard Business Review*, 1993, *11*, pp. 316-326.

Ekboir, J. “Potential Impact of Foot and Mouth Disease in California.” *Agricultural Issues Center Division of Agriculture and Natural Resources*. University of California,1999.

Elbakidze, L. “An Economic Exploration of Prevention Versus Response in Animal Related Bioterrorism Decision Making.” *Unpublished Ph.D. Dissertation, Department of Agricultural Economics,* Texas A&M University*,* 2004.

Elbakidze, L. **and McCarl, B.** “Ex Ante VS Ex Post Bioterrorism Mitigation.” *Department of Agricultural Economics, Texas A&M University, Paper Presented at the American Agricultural Economic Association Meeting in Rhode Island,* 2005

Engle, R.F. “Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U.K. Inflation.” *Econometrica*, 1982, *50*, pp. 987–1008.

George, P.S. and King, G.A. “Consumer Demand for Food Commodities in the United States with Projections for 1980.” *Giannini Foundation Monograph*, 1971, *26*.

Godfrey, B. "Dairy Compacts: Lessons Learned from the Northeast Compact." *Dairy Newsletter,* Department of Economics, Utah State University, 2001.

Goodwin, B.K. and Harper, D.C. "Price Transmission, Threshold Behavior, and Asymmetric Adjustment in the US Pork Sector.*" Journal of Agricultural and Applied Economics*, 2000, *32*, pp. 543-553.

Goodwin, B.K. and Holt, M.T. "Asymmetric Adjustment and Price Transmission in the US Beef Sector." *American Journal of Agricultural and Applied Economics*, 1999, *81*, pp. 630-637.

Goodwin, B.K. and Piggott, N.E. "Spatial Market Integration in the Presence of Threshold Effects." *American Journal of Agricultural and Applied Economics*, 2001, *83* (2), pp. 302-317.

Granger, C.W.J. and Lee, T.H. "Investigation of Production, Sales, and Inventory Relationships Using Multicointegration and Non-Symmetric Error Correction Models." *Journal of Applied Economics*, 1989, *4*, pp. 145-159.

Griffith, G.R. and N.E. Piggott. "Asymmetry in Beef, Lamb and Pork Farm-Retail Price Transmission in Australia." *Agricultural Economics*, 1994, *10*, pp. 307-316.

Hahn, W.F. "Price Transmission Asymmetry in Pork and Beef Markets." *The Journal of Agricultural Economics Research*, 1990, *42*, pp. 21-30.

Hall, L.L.; Tomek, W.G.; Ruther, D.L.; and Kyerine, S.S. "Case Studies in the Transmission of Farm Price." *Department of Agricultural Economics,Cornell University, Agricultural Economics Research,* 1981, Working Paper No 81-12.

Houck, P.J. "An Approach to Specifying and Estimating Non-Reversible Functions." *American Journal of Agricultural Economics*. 1977, *59*, pp. 570-572.

Jin, Y.; Huang, W. and McCarl, B.A. "Economics of Homeland Security: Carcass Disposal and the Design of Animal Disease Defense" *Department of Agricultural Economics, Texas A&M University*, Unpublished Manuscript, 2005

Johansen, S. *Likelihood-based Inference in Cointegrated Vector Autoregressive Models.* Oxford: Oxford University Press, 1995.

Johansen, S. and Juselius, K. "Maximum Likelihood Estimation and Inferences on Cointegration—with Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics*, 1990, *52*, pp. 169–210.

Kinnucan, H.W. and Forker, O.D. "Asymmetry in Farm-Retail Price Transmission for Major Dairy Products*." American Journal of Agricultural Economics.* 1987, *69*, pp. 285-292.

Kohnen, A. "Responding to the Threat of Agroterrorism: Specific Recommendations for the United States Department of Agriculture." *BSCIA* discussion paper, Harvard University, 2000, *29*.

Kramer, L. "Alternative Methods for Robust Analysis in Event study Applications." *Advances in Investment Analysis and Portfolio Management*, 2001, pp. 108-132.

Lamm, R.M. and Westcott, P.C. "The Effects of Changing Input Costs on Food Prices." *American Journal of Agricultural Econometrics.* 1981, *63*, pp. 187-196.

Larsen, G.A., Jr. and Resnick, B. "A Performance Comparison between Crosssectional Stochastic Dominance and Traditional Event Study Methodologies." *Review of Quantitative Finance and Accounting*, 1999, *12*, pp. 103-112.

Lass, D.; Mawunyo, A. and Geofrey, A. "Impacts of the Northeast Dairy Compact on New England Retail Prices." *Agricultural and Resource Economics Review.* 2001, *30* (1). pp. 83-92.

Lawrence, J. and Otto, D. "Economic Importance of the Texas Cattle Industry." National Cattlemen's Beef Association. [On-line] Available at: http://www.beef.org/NEWSECONOMICIMPORTANCEOFTHETEXASCATTLEINDUSTRY2714.aspx (2005)

MacKinlay, C. "Event Studies in Economics and Finance." *Journal of Economic Literature*, March 1997, *35*, pp. 13-39.

Marais, M. L. "An Application of the Bootstrap Method to the Analysis of Squared, Standardized Market Model Prediction Errors." *Journal of Accounting Research*, 1984, *22* Supplement, pp. 34-54.

Marcus, R.; Swilder, S. and Zivney, T. " An Explanation of Why Shareholders' Loss Are So Large After Drug Recalls." *Managerial and Decision Economics*, 1987, *8,* pp. 295-300.

Markowitz, H.M. *Portfolio Selection, Efficient Diversification of Investments*. New York: John Wiley and Sons, Inc., 1959.

McCarl, B. "Contribution to Carcass Disposal Handbook on Economic and Cost Factors,*"Department of Agricultural Economics, Texas A&M University,* Unpublished Manuscript, 2006.

McCauley, H.; New, J.; Nasser, A.; Sundquist, W.B. and Miller, W. "A Study of the Potential Economic Impact of Foot-and-Mouth Disease in the United States" Published by the USDA and University of Minnesota, 1979.

McClaskey, J.; Fox, J.; Marsh, T.L.; Nutsch, A.; Kastner, J.; Doering O. and Foster, K. "Economic and Cost Considerations." Ch. 9, Carcass Disposal: A Comprehensive Review, USDA-APHIS and National Agricultural Biosecurity Center Consortium. 2004.

Meltzner, M.; Cox, N. and Fukuda, K. "The Economic Impact of Pandemic Influenza in the United States: Priorities for Intervention." Center for Disease Control and Prevention, Atlanta, GA, CDC, 2003.

Mewissen, M.; Horst, S.; Huirne, R. and Dijkhuizen, A. "A Model to Estimate the Financial Consequences of Classical Swine Fever Outbreaks: Principles and Outcomes." *Preventive Veterinary Medicine,* 1999, *42*, pp. 249-270.

Miller, D.J. and Hayenga, M.L. "Price Cycles and Asymmetric Price Transmission in the U.S. Pork Market." *American Journal of Agricultural Economics.* 2001, *83*, pp. 551-562.

Mohanty, S.; Peterson, E.W. F. and Kruse, N.C. "Price Asymmetry in the International Wheat Market." *Canadian Journal of Agricultural Economics.* 1995, *43*, pp. 355-366.

Morris, R.S.; Wilesmith, J.W.; Stern, M.W.; Sanson, R.L. and Stevenson, M.A. "Predictive Spatial Modeling of Alternative Control Strategies for the Foot-and-Mouth Disease Epidemic in Great Britain." *Veterinary Record,* 2001. *149*, pp. 137-144.

Nielen, M.; Jalvingh, A.; Horst, S.; Dijkhuizen, A.; Maurice, H.; Schut, B.H.; van Wuijckhuse, L.A. and de Hong. "Quantification of Contacts between Dutch Farms to Asses the Potential Risk of Foot-and-Mouth Disease Spread." *Preventive Veterinary Medicine*, 1996, *28*, pp. 143-158.

Nielen, M.; Jalvingh, A. W.; Meuwissen, M.P.M.; Horst, S.H. and Dijkhuizen, A.A. "Spatial and Stochastic Simulation to Evaluate the Impact of Events and Control Measures on the 1997-1998 Classical Swine Fever Epidemic in The Netherlands." *Preventive Veterinary Medicine*,, 1999, *42*, pp. 297-317.

Peltzman, S. "Prices Rise Faster Than They Fall." *Journal of Political Economy*. 2000, *108*, pp. 466-502.

Pick, D.H.; Karrenbrock, J. and Carmen, H.F. "Price Asymmetry and Marketing Margin Behavior: An Example for California-Arizona Citrus." *Agribusiness.* 1990, *6*, pp. 75-84.

Punyawadee, V.; Boyd, M.S. and Faminow, M.D. "Testing for Asymmetric Pricing in the Alberta Pork Market." *Canadian Journal of Agricultural Economics.* 1991, *39*, pp. 493-501.

Ries, J. "Windfall Profits and Vertical Relationship: Who Gained in the Japanese Auto Industry from VERs?." *The Journal of Industrial Economics*, 1993, *43*, pp. 259-276.

Salin, V. and Hooker, N. "Stock Market Reaction to Food Recalls." *Review of Agricultural Economics*, 2001, *23* (1), pp. 33-46.

Schoenbaum, M.A. and Disney, W.T. "Modeling Alternative Mitigation Strategies for a Hypothetical Outbreak of Food-and-Mouth Disease in the United States." *Preventive Veterinary Medicine*, 2003, *58*, pp. 25-32.

Sharpe, W. "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk." *The Journal of Finance*, 1964, *19* (3), pp. 425-442.

Thomas, L. "Grower Fears Devastation Unless Source of Virus Found." *Pittsburgh Post-Gazette*, Wednesday, November 26, 2003.

Thompson, D.; Muriel, P.; Russell, D.; Osborne, P.; Bromley, A.; Rowland, M.; Creigh-Tyte, S. and Brown, C. "Economic Costs of Foot and Mouth Disease Outbreak in United Kingdom in 2001." Department for Environmental, Food and Rural Affairs, UK. 2003. [On-line] Available at: http://www.defra.gov.uk/corporate/inquiries/lessons/fmdeconcostrev.pdf Last Accessed 10/06/04.

Thompson, R. "Conditioning the Return-Generating Process on Firm Specific Events: A Discussion of Event Study Methods." *Journal of Financial and Quantitive Analysis*, 1985, *20* (2), pp. 151-168.

Tweeten, L. *Terrorism, Radicalism, and Populism in Agriculture.* Iowa: Iowa State Press, 2003.

USDA "Quarantine and Movement Control" (2003). National Animal Health Emergency Management System Guidelines U.S. Department of Agriculture

USDA "Agricultural Income and Finance Outlook." Electronic Outlook Report from the Economic Research Service (2005)

USDA-Agricultural Marketing Service "Livestock and Seed Program" Electronic Report Available at: http://www.ams.usda.gov/lsmnpubs/Live.htm, Dates on Data Accessed: May 2006

USDA-APHIS-VS, *Foot-and-Mouth Disease Emergency Disease Guidelines.* Veterinary Services, Animal and Plant Health Inspection Service, US Department of Agriculture, 1991, Washington, DC.

von Cramon-Taubadel, S. "Estimating Asymmetric Price Transmission With the Error Correction Representation: An Application to the German Pork Market." *European Review of Agricultural Economics,* 1998, *25*, pp. 1-18.

von Cramon-Taubadel, S. and Fahlbusch, S. "Identifying Asymmetric Price Transmission with Error Correction Models." Poster Session EAAE European Seminar in Reading, England 1994

von Cramon-Taubadel, S. and Loy, J.P. "The Identification of Asymmetric Price Transmission Processes with Integrated Time Series." *Jahrbucher for Nationalokonomie und Statistik*, 1999, *218*, pp. 85-106.

von Cramon-Taubadel, S. and Meyer, J. "Asymmetric Price Transmission: Fact or Artifact?." Department of Agricultural Economics, Gottingen, Germany. 2000, Working Paper.

Wang, Z.; Salin, V.; Hooker, N. and Leatham, D. "Stock Market Reaction to Food Recalls: a GARCH Application." *Applied Economic Letters*, 2002, *9*, pp. 979-987.

Ward, Michael.P; Laffan, S.P. and Highfield, L.D. "The Potential Impact of Foot-and-Mouth Disease Virus Introduction in Domestic Cattle, Feral Pig and Wild Deer Populations: Use of a Geographical Automata System." *Epidemiology and Infection.* In press, 2006.

Ward, R.W. "Asymmetry in Retail, Wholesale and Shipping Point Pricing for Fresh Vegetables." *American Journal of Agricultural Economics,* 1982, *64*, pp. 205-212.

Willett, L.S.; Hansmire, M.R. and Bernard, J.C. "Asymmetric Price Response Behavior of Red Delicious Apples." *Agribusiness,* 1997, *13*, pp. 649-658.

Wolffram, R. "Positive Measure of Aggregate Supply Elasticities: Some New Approaches and Some Critical Notes*." American Journal of Agricultural Economics,* 1971, *53*, pp. 356-359.

Zhang, P.; Fletcher, S.M. and Carley, D.H. “Peanut Price Transmission Asymmetry in Peanut Butter.” *Agribusiness*, 1995, *115*, pp. 13-20.

APPENDIX A

Table 2.1. Granger Causality Tests from 1994:01 to 2002:10 Based on Monthly Data of Farm and Retail Prices for Whole Milk[a]

City	Effect	Hypothesized Cause	F-statistic	P-value
Atlanta	Farm Price	Retail Price	0.65	0.5217
Atlanta	Retail Price	Farm Price	3.31	0.0406*
Boston	Farm Price	Retail Price	1.69	0.1881
Boston	Retail Price	Farm Price	0.04	0.9612
Chicago	Farm Price	Retail Price	0.55	0.5814
Chicago	Retail Price	Farm Price	4.55	0.0219*
Dallas	Farm Price	Retail Price	0.92	0.4010
Dallas	Retail Price	Farm Price	9.00	0.0003*
Hartford	Farm Price	Retail Price	0.04	0.9652
Hartford	Retail Price	Farm Price	0.75	0.4755
Seattle	Farm Price	Retail Price	0.13	0.8799
Seattle	Retail Price	Farm Price	6.28	0.0027*
St. Louis	Farm Price	Retail Price	0.35	0.3474
St. Louis	Retail Price	Farm Price	22.69	0.0000*

* indicates statistical significance at the 0.05 level.
a The null hypothesis is that one series does not Granger cause another. The Granger causality tests use a lag length of two months.

Table 2.2. Granger Causality Tests from 1994:01 to 2002:10 Based on Monthly Data of Farm and Retail Prices for Two Percent Milk[a]

City	Effect	Hypothesized Cause	F-statistic	P-value
Atlanta	Farm Price	Retail Price	0.19	0.8308
Atlanta	Retail Price	Farm Price	3.36	0.0387*
Boston	Farm Price	Retail Price	1.25	0.2898
Boston	Retail Price	Farm Price	0.42	0.6607
Chicago	Farm Price	Retail Price	1.03	0.3580
Chicago	Retail Price	Farm Price	10.79	0.0001*
Dallas	Farm Price	Retail Price	0.43	0.6536
Dallas	Retail Price	Farm Price	5.92	0.0037*
Hartford	Farm Price	Retail Price	0.18	0.8348
Hartford	Retail Price	Farm Price	0.72	0.4899
Seattle	Farm Price	Retail Price	0.55	0.5792
Seattle	Retail Price	Farm Price	6.09	0.0032*
St. Louis	Farm Price	Retail Price	2.02	0.1378
St. Louis	Retail Price	Farm Price	32.65	0.0000*

* indicates statistical significance at the 0.05 level.
[a] The null hypothesis is that one series does not Granger cause another. The Granger causality tests use a lag length of two months.

Table 2.3. Descriptive Statistics of Whole Milk Prices at the Farm and Retail Level of the Marketing Channel

City	Mean	Median	Standard Deviation	Minimum	Maximum
			Farm Prices – Whole Milk		
Atlanta	1.41	1.38	0.14	1.13	1.83
Boston	1.46	1.47	0.12	1.25	1.78
Chicago	1.36	1.32	0.14	1.15	1.75
Dallas	1.37	1.34	0.12	1.16	1.76
Hartford	1.45	1.47	0.12	1.24	1.77
Seattle	1.28	1.26	0.13	1.05	1.66
St. Louis	1.37	1.35	0.14	1.13	1.75
			Retail Prices – Whole Milk		
Atlanta	2.67	2.69	0.42	1.98	3.29
Boston	2.66	2.61	0.23	2.33	3.08
Chicago	2.99	2.95	0.26	2.66	3.49
Dallas	2.63	2.62	0.28	2.22	3.22
Hartford	2.68	2.68	0.23	2.38	3.10
Seattle	3.29	3.18	0.30	2.92	3.92
St. Louis	2.80	2.92	0.30	2.24	3.26

Table 2.4. Descriptive Statistics of Two Percent Milk Prices at the Farm and Retail Level of the Marketing Channel

City	Mean	Median	Standard Deviation	Minimum	Maximum
			Farm Prices – Two Percent Milk		
Atlanta	1.29	1.25	0.12	1.03	1.68
Boston	1.33	1.33	0.10	1.14	1.63
Chicago	1.23	1.20	0.13	0.91	1.60
Dallas	1.24	1.21	0.11	0.96	1.61
Hartford	1.32	1.32	0.10	1.13	1.63
Seattle	1.15	1.14	0.12	0.94	1.51
St. Louis	1.24	1.22	0.13	0.96	1.60
			Retail Prices – Two Percent Milk		
Atlanta	2.67	2.69	0.42	1.98	3.22
Boston	2.54	2.47	0.29	2.14	3.05
Chicago	2.78	2.72	0.37	2.26	3.39
Dallas	2.63	2.62	0.28	2.12	3.22
Hartford	2.61	2.56	0.27	2.25	3.07
Seattle	3.17	3.09	0.30	2.72	3.82
St. Louis	2.74	2.85	0.31	2.16	3.23

Table 2.5. Empirical Results of the Johansen Cointegration Tests for Farm Prices and Retail Prices of Whole Milk

City	Hypothesized Number of Cointegrated Equation	Trace Statistic	P-Value	Maximal Eigenvalue Statistic	P-Value
Atlanta	None	20.79	0.0072*	18.38	0.0106*
	At most 1	2.41	0.1202	2.41	0.1202
Boston	None	8.23	0.4407	8.20	0.3581
	At most 1	0.03	0.8674	0.03	0.8674
Chicago	None	19.93	0.0100*	17.85	0.0129*
	At most 1	2.07	0.1498	2.07	0.1498
Dallas	None	23.95	0.0021*	22.46	0.0021*
	At most 1	1.49	0.2215	1.49	0.2215
Hartford	None	6.95	0.5826	6.84	0.5076
	At most 1	0.11	0.7378	0.11	0.7378
Seattle	None	12.00	0.1568	11.25	0.1420
	At most 1	0.75	0.3867	0.75	0.3867
St. Louis	None	11.86	0.1636	14.26	0.0742
	At most 1	2.71	0.0992	2.71	0.0992

* EVIEWS 5.0 was the statistical package employed to conduct these cointegration rank tests. The intercept (no trend) option with four lags was used in conjunction with these tests. The level of significance chosen for this analysis was 0.05.

Table 2.6. Empirical Results of the Johansen Cointegration Rank Tests for Farm Prices and Retail Prices of Two Percent Milk

City	Hypothesized Number of Cointegrated Equation	Trace Statistic	P-Value	Maximal Eigenvalue Statistic	P-Value
Atlanta	None	31.43	0.0001*	28.99	0.0001*
	At most 1	2.44	0.1178	2.44	0.1178
Boston	None	14.37	0.0733	13.85	0.0580
	At most 1	0.52	0.4715	0.52	0.4715
Chicago	None	26.92	0.0006*	24.94	0.0007*
	At most t 1	1.98	0.1587	1.98	0.1587
Dallas	None	23.28	0.0027*	21.89	0.0026*
	At most 1	1.39	0.2378	1.39	0.2378
Hartford	None	11.80	0.1668	11.53	0.1294
	At most 1	0.26	0.6071	0.26	0.6071
Seattle	None	18.10	0.0198*	17.25	0.0163*
	At most 1	0.85	0.3568	0.85	0.3568
St. Louis	None	22.00	0.0045*	18.43	0.0103*
	At most 1	3.57	0.0589	3.57	0.0589

* EVIEWS 5.0 was the statistical package employed to conduct these cointegration rank tests. The intercept (no trend) option with four lags was used in conjunction with these tests. The level of significance chosen for this analysis was 0.05.

Table 2.7. Variable Definitions for Tables 2.8-2.11

Term	Implication
ΔP^{+}_{ft} (SR+)	Positive Change in Farm Price in the Short- run (Contemporaneous Change)
ΔP^{+}_{ft-i}	Positive Change in Farm Price Lagged *i* Periods
LR+	Positive Cumulative Change in the Long Run
ΔP^{-}_{ft} (SR-)	Negative Change in Farm Price in the Short- run (Contemporaneous Change)
ΔP^{+}_{ft-i}	Negative Change in Farm Price Lagged *i* Period
LR-	Negative Cumulative Change in the Long Run

Table 2.8. Empirical Results of the Houck Procedure for Whole Milk

Variable	Atlanta	Boston	Chicago	Dallas	Hartford	Seattle	St. Louis
Intercept	-0.003674[a]	-0.006278	-0.006940	0.013621	-0.003446	-0.004268	0.008727
	(0.5553)[b]	(0.1315)	(0.5363	(0.1418)	(0.4544)	(0.6176)	(0.2678)
ΔP^{+}_{ft} (SR+)	0.27510	0.45386	0.44294	0.23056	0.41118	0.22775	0.27159
	(0.0014)	(0.0000)	(0.0001)	(0.0338)	(0.0000)	(0.0027)	(0.0015)
ΔP^{+}_{ft-1}	0.27510	0.45386	0.44294	0.23056	0.41118	0.30366	0.27159
	(0.0014)	(0.0000)	(0.0001)	(0.0338)	(0.0000)	(0.0027)	(0.0015)
ΔP^{+}_{ft-2}	--	--	0.16940	0.21221	--	0.22775	--
			(0.0012)	(0.0000)		(0.0027)	
LR^{+}	0.55019	0.90773	0.88589	0.46112	0.82235	0.75915	0.54317
	(0.0014)	(0.0000)	(0.0001)	(0.0338)	(0.0000)	(0.0027)	(0.0015)
ΔP^{-}_{ft} (SR-)	0.04957	0.11877	0.16940	0.21221	0.13221	0.14008	0.28594
	(0.2215)	(0.0203)	(0.0012)	(0.0000)	(0.0069)	(0.0237)	(0.0000)
ΔP^{-}_{ft-1}	0.04957	0.11877	0.22587	0.28294	0.13221	0.14008	0.28594
	(0.2215)	(0.0203)	(0.0012)	(0.0000)	(0.0069)	(0.0237)	(0.0000)
ΔP^{-}_{ft-2}	--	--	0.16940	0.21221	--	--	--
			(0.0012)	(0.0000)			
LR^{-}	0.09914	0.23754	0.56467	0.70738	0.26442	0.28015	0.57188
	(0.2215)	(0.0203)	(0.0012)	(0.0000)	(0.0069)	(0.0237)	(0.0000)
AR(1)	--	-0.222235	--	-.151807	--	-0.369191	--
		(0.0228)		(0.1359)		(0.0002)	
AR(2)	--	-0.358957	--	--	--	--	--
		(0.0228)					
R^2	0.2115	0.3537	0.2496	0.2157	0.3402	0.2113	0.3325
DW	2.05	2.10	2.10	2.05	2.17	2.01	2.24
SIC	-3.2477	-3.2955	-2.1980	2.3026	-3.8033	-2.4033	-2.8426
AIC	-3.3240	-3.4241	-2.2747	2.4055	-3.8796	-2.5062	-2.9189

[a] Parameter estimate
[b] p-value
c Variable definitions are found in Table 2.7

Table 2.9. Empirical Results of the Houck Procedure for Two Percent Milk

Variable	Atlanta	Boston	Chicago	Dallas	Hartford	Seattle	St. Louis
Intercept	-0.002636[a]	-0.007404	-0.006115	0.017055	-0.004233	-0.000960	0.01078
	(0.6576)[b]	(0.1422)	(0.5837)	(0.1170)	(0.3340)	(0.9134)	(0.0990)
ΔP^{+}_{ft} (SR^{+})	0.28877	0.43083	0.46785	0.07757	0.38266	0.19077	0.21396
	(0.0000)	(0.0000)	(0.0000)	(0.1610	(0.0000)	(0.0053)	(0.0000)
ΔP^{+}_{ft-1}	0.28877	0.43083	0.46785	0.11635	0.38266	0.25437	0.28528
	(0.0000)	(0.0000)	(0.0000)	(0.1610)	(0.0000)	(0.0053)	(0.0000)
ΔP^{+}_{ft-2}	--	--	--	0.11635	--	0.19077	0.21396
				(0.1610)		(0.0053)	(0.0000)
ΔP^{+}_{ft-3}	--	--	--	0.07757	--	--	--
				(0.1610)			
LR^{+}	0.57753	0.86165	0.93570	0.38785	0.76532	0.63592	0.71321
	(0.0000)	(0.0000)	(0.0000)	(0.1610)	(0.0000)	(0.0053)	(0.0000)
ΔP^{-}_{ft} (SR^{-})	0.03257	0.11671	0.26141	0.22394	0.13135	0.16906	0.38307
	(0.4227)	(0.0574)	(0.0009)	(0.0001)	(0.0191)	(0.0237)	(0.0000)
ΔP^{-}_{ft-1}	0.03257	0.1167)	0.26141	0.29858	0.13135	016906	0.38307
	(0.4227)	(0.0574)	(0.0009)	(0.0001)	(0.0191)	(0.0237)	(0.0000)
ΔP^{-}_{ft-2}	--	--	--	0.22394	--	--	--
				(0.0001)			
LR^{-}	0.06514	0.23342	0.52281	0.74647	0.26270	0.33811	0.76614
	(0.4227)	(0.0574)	(0.0009)	(0.0001)	(0.0191)	(0.0237)	(0.0000)
AR(1)	--	-0.216414	--	--	--	-0.416440	-0276731
		(0.0223)				(0.0000)	(0.0054)
AR(2)	--	-0.421606	--	--	-0.349744	--	--
		(0.0000)			(0.0003)		
R^2	0.1826	0.3643	0.2784	0.1682	0.3877	0.2368	0.4342
DW	2.01	2.21	2.17	2.25	2.29	2.03	2.07
SIC	-3.3355	-3.0374	-2.1111	-2.2891	-3.5327	-2.1024	-2.7567
AIC	-3.4113	-3.1653	-2.1870	-2.3659	-3.6613	-2.2047	-2.8590

[a] Parameter estimate
[b] p-value
[c] Variable definitions are found in Table 2.7

Table 2.10. Error Correction Model Results for Whole Milk

Vqriqble	Atlanta	Chicago	Dallas
Intercept	-0.002137[a]	-0.005022	0.020109
	(0.7603)[b]	(0.6858)	(0.0908)
ΔP_{ft}^{+} (SR^{+})	0.31739	0.48246	0.32577
	(0.0000)	(0.0001)	(0.0097)
ΔP_{ft-1}^{+}	0.31739	0.48246	0.32477
	(0.0000)	(0.0001)	(0.0097)
LR+	0.63478	0.96492	0.65153
	(0.0000)	(0.0001)	(0.0097)
ΔP_{ft}^{-} (SR^{-})	0.03149	0.1713	0.2479
	(0.1449)	(0.0023)	(0.0000)
ΔP_{ft-1}^{-}	0.04723	0.2284	0.33054
	(0.1449)	(0.0023)	(0.0000)
ΔP_{ft-2}^{-}	0.04723	0.1713	0.2479
	(0.1449)	(0.0023)	(0.0000)
ΔP_{ft-3}^{-}	0.03149	--	--
	(0.1449)		
LR-	0.15744	0.57171	0.82635
	(0.1449)	(0.0023)	(0.0000)
ECT_{t-1}^{+}	-0.127414	0.012534	1.31208
	(0.3294)	(0.9226)	(0.0945)
ECT_{t-1}^{-}	-0.125466	0.123136	1.488138
	(0.3595)	(0.3607)	(0.0514)
ΔP_{rt-1}	--	-0.137828	-1.567282
		(0.2844)	(0.0505)
ΔP_{rt-2}	-0.216006	--	1.22297
	(0.0733)		(0.0965)
ΔP_{rt-3}	-0.165305	--	--
	(0.0876)		
ΔP_{rt-4}	--	--	--
R2	0.2588	0.2626	0.2573
DW	1.87	1.980	2.06
F-statistic For Model Superiority	Lag structure different	0.5695	1.9373
		(0.6364)	(0.1104)
AIC	-3.2877	-2.2339	-2.4122
SIC	-3.1075	-2.0805	-2.2332

[a] Parameter estimate
[b] p-value
[c] Variable definitions are found in Table 2.7

Table 2.11. Error Correction Model Results for Two Percent Milk

Variable	Atlanta	Chicago	Dallas	Seattle	St. Louis
Intercept	-0.001856[a]	-0.005114	0.024648	-0.013962	0.020099
	(0.8184)[b]	(0.7017)	(0.0577)	(0.3009)	(0.0333)
ΔP^{+}_{ft} (SR^{+})	0.31075	0.4937	0.09969	0.26451	0.2739
	(0.0000)	(0.0000)	(0.0772)	(0.0052)	(0.0000)
ΔP^{+}_{ft-1}	0.31075	0.4937	0.14953	0.35266	0.3652
	(0.0000)	(0.0000)	(0.0772)	(0.0052)	(0.0000)
ΔP^{+}_{ft-2}	--	--	0.14953	0.26451	0.2739
			(0.0772)	(0.0000)	(0.0000)
ΔP^{+}_{ft-3}	--	--	0.09969	--	--
			(0.0772)		
LR+	0.6215	0.9874	0.49843	0.88171	0.91301
	(0.0000)	(0.0000)	(0.0772)	(0.0052)	(0.0000)
ΔP^{-}_{ft} (SR^{-})	0.01105	0.19443	0.24388	0.19699	0.25545
	(0.4209)	(0.0012)	(0.0000)	(0.0373)	(0.0000)
ΔP^{-}_{ft-1}	0.01894	0.25923	0.32518	0.19699	0.38317
	(0.4209)	(0.012)	(0.0000)	(0.0373)	(0.0000)
ΔP^{-}_{ft-2}	0.02368	0.19443	0.24388	--	0.38317
	(0.4209)	(0.0012)	(0.0000)		(0.0000)
ΔP^{-}_{ft-3}	0.02526	--	--	--	0.25545
	(0.4209)				(0.0000)
ΔP^{-}_{ft-4}	0.02368	--	--	--	--
	(0.4209)				
ΔP^{-}_{ft-5}	0.01894	--	--	--	--
	(0.4209)				
ΔP^{-}_{ft-6}	0.01105	--	--	--	--
	(0.4209)				
LR-	0.1326	0.64808	0.81294	0.39399	1.27723
	(0.4209)	(0.0012)	(0.0000)	(0.0373)	(0.0000)
ECT^{+}_{t-1}	-0.029021	-0.082744	0.046736	0.125001	-0.274774
	(0.8185)	(0.4599)	(0.6976)	(0.3158)	(0.0363)
ECT^{-}_{t-1}	-0.75598	-0.120677	0.221971	-0.125171	-0.398899
	(0.5772)	(0.3332)	(0.0978)	(0.3674)	(0.0000)
ΔP_{rt-1}	--	--	-0.262951	-0.428779	--
			(0.0602)	(0.0158)	
ΔP_{rt-2}	--	-0.125292	--	--	-0.548005
		(0.2344)			(0.0000)
ΔP_{rt-3}	-0.204251	--	--	0.13835	--
	(0.0431)			(0.1735)	
F-statistic for model superiority	Lag structure different	Lag structure different	1.3841 (0.2523)	6.3396 (0.0001)	Lag structure different
R2	0.2304	0.2920	0.2024	0.2715	0.4711
DW	2.04	1.99	2.08	1.94	2.01
AIC	-3.3749	-2.1275	-2.3495	-2.1819	-2.8875
SIC	-3.2196	-1.9740	-2.1960	-2.0018	-2.7341

[a] Parameter Estimate
[b] p-value
[c] Variable definitions are found in Table 2.7

Table 2.12. Elasticities of Price Transmission for Whole Milk with the Houck Approach

	Atlanta	Boston	Chicago	Dallas	Hartford	Seattle	St. Louis
EPT_POS_SR[a]	0.1527	0.2637	0.2091	0.1247	0.2360	0.0923	0.1386
EPT_NEG_SR[b]	0.0258	0.0630	0.0737	0.1077	0.0693	0.0517	0.1306
EPT_POS_LR[c]	0.3054	0.5275	0.4182	0.2494	0.4720	0.3077	0.2772
EPT_NEG_LR[d]	0.0516	0.1261	0.2459	0.3592	0.1386	0.1034	0.2613

[a] EPT_POS_SR short run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long run elasticity of price transmission for falling farm prices

Table 2.13. Elasticities of Price Transmission for Two Percent Milk with the Houck Approach

	Atlanta	Boston	Chicago	Dallas	Hartford	Seattle	St. Louis
EPT_POS_SR[a]	0.1451	0.2377	0.2148	0.0375	0.2046	0.0717	0.1008
EPT_NEG_SR[b]	0.1059	0.0596	0.1135	0.1048	0.0650	0.0597	0.1660
EPT_POS_LR[c]	0.2902	0.4754	0.4297	0.1878	0.4092	0.2390	0.3360
EPT_NEG_LR[d]	0.0319	0.1193	0.2270	0.3494	0.1301	0.1194	0.3321

[a] EPT_POS_SR short run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long run elasticity of price transmission for falling farm prices

Table 2.14. Elasticities of Price Transmission for Whole Milk with the ECM Approach

	Atlanta	Chicago	Dallas
EPT_POS_SR[a]	0.1761	0.2278	0.1762
EPT_NEG_SR[b]	0.0164	0.0746	0.1258
EPT_POS_LR[c]	0.3523	0.4556	0.3524
EPT_NEG_LR[d]	0.0820	0.2486	0.4196

[a] EPT_POS_SR short run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long run elasticity of price transmission for falling farm prices

Table 2.15. Elasticities of Price Transmission for Two Percent Milk with the ECM Approach

	Atlanta	Chicago	Dallas	Seattle	St. Louis
EPT_POS_SR[a]	0.1561	0.2267	0.0482	0.0994	0.1290
EPT_NEG_SR[b]	0.0054	0.0844	0.1141	0.0695	0.1107
EPT_POS_LR[c]	0.3123	0.4534	0.2414	0.3315	0.4301
EPT_NEG_LR[d]	0.0650	0.2814	0.3805	0.1391	0.5536

[a] EPT_POS_SR short run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long run elasticity of price transmission for falling farm prices

APPENDIX B

Table 3.1. Symbol and Variable Definitions

Symbol	Firm
S&P500	S&P 500 Index
PRND	Prandium Inc.
SYS	Sysco Corporation
OSI	Outback Steakhouse, Inc.
DRI	Darden Restaurants, Inc.
EAT	Brinker International, Inc.
APPB	Applebee's International Incorporated
RMK	Aramark Corp
PFGC	Preformance Food Group Company
SUV	Supervalu, Inc
AHO	Koninkiljke Ahold NV

Table 3.2. Descriptive Statistics for the Companies' Rates of Return

Variable	Date Range	N	Mean	Median	Std.Dev.	Minimum	Maximum
PRND	1	120	0.019054	0	0.309235	-0.38824	2.823529
S&P500-1	1	120	0.00104	0.001836	0.008995	-0.02492	0.022385
SYS-2	2	120	-0.00063	-0.00155	0.010089	-0.02641	0.023451
S&P500-2	2	120	-0.00022	0.000504	0.007166	-0.01556	0.016365
SYS-3	3	141	-0.0010	0.012092	-0.0018	-0.0730	0.0329
S&P500-3	3	141	-0.0002	0.007336	0.000468	-0.01632	0.016365
OSI	3	141	-0.00075	-0.00096	0.015421	-0.05756	0.031568
DRI	3	141	-0.00023	-0.00136	0.013811	-0.03828	0.056911
EAT	3	141	-0.00112	-0.00028	0.014258	-0.07602	0.034574
APPB	3	141	-0.00263	-0.00083	0.032068	-0.3329	0.074155
RMK	3	141	-0.00037	0	0.012095	-0.04263	0.032122
PFGC	3	141	-0.00239	-0.0012	0.022575	-0.18509	0.070103
SUV	3	141	-0.00051	-0.00128	0.013143	-0.04351	0.039837
AHO	3	141	-0.0018	-0.00288	0.021295	-0.07989	0.045882

Note: Units of Rates of Return are presented in decimal form.
There are three different data ranges: 1,2,3.
Data Range 1: May 15, 2003 to Nov 3, 2003.
Data Range 2: February 10, 2004 to August 3, 2004.
Data Range 3: February 10, 2004 to August 31, 2004.
Variable definitions are found in Table 3.1

Table 3.3. Estimated Parameters of the Event Study Models for Prandium and Sysco

	Prandium Simple market model	Sysco Simple market model	Sysco GARCH approach
β_0	0.0177	-0.0004	-0.000887
P-value	0.5350	0.53	0.3020
β_1	1.2587	0.573	0.56217
P-value	0.6914	0	0
D_1	-	0.002	0.00610
P-value	-	0.712	.5983
D_2	-	-0.004	-0.02898
P-value	-	0.557	0..9983
D_3	-	-	-0.00234
P-value	-	-	0.9877
D_4			-0.00056
P-value			0.9497
D_5			-0.0372
P-value			0.7657
α_0	-	-	8.86E-05
P-value	-	-	0.016
α_1	-	-	0.201788
P-value	-	-	0.1761
φ_1	-	-	-0.292592
P-value	-	-	0.5261
D_6	-	-	0.000418
P-value	-	-	0.0447
Observations	120	120	141
R_2	0.002	0.171	0.081917
DW	1.98	1.855	2.321533
SIC	-2.327	-9.269	-6.05485
AIC	-2.35	-9.339	-6.24307
Iterations			477

Table 3.4. Empirical Results of the White Test for Sysco Equation (7) Simple Market Model Specification

White Heteroskedasticity Test:			
F-statistic	0.629094	Probability	0.642711
Obs*R-squared	2.569559	Probability	0.632225

Table 3.5. Testing for Sysco Abnormal Rates of Returns

Day of the event	
Sysco t	-0.00695
Sysco t *hat*	0.001172
Abnormal Returns	-0.00812
CI up	0.011281
CI down	-0.02518
Day after the event	
Sysco t+1	-0.00175
Sysco t+1 *hat*	-0.00447
Abnormal Returns	0.002722
CI up	0.016482
CI down	-0.01998
Two days after the event	
Sysco t+2	-0.01431
Sysco t+2 *hat*	-0.00149
Abnormal Returns	-0.01281
CI up	0.003924
CI down	-0.03254
Three days after the event	
Sysco t+3	-0.01511
Sysco t+3 *hat*	-0.00868
Abnormal Returns	-0.00642
CI up	0.003124
CI down	-0.03334
Four days after the event	
Sysco t+4	0.004511
Sysco t+4 *hat*	-0.00914
Abnormal Returns	0.013654
CI up	0.022742
CI down	-0.01372

Note: *t* is the day of the event. (August 3, 2004)
hat is the forecast one day prior the event.
Abnormal returns is calculated using formula (2)
CI refers to the Confidence Intervals in formula (3)

Table 3.6. White Test Results for GARCH Specification

F-statistic	21.45698	Probability	0.000000
Obs*R-squared	62.43547	Probability	0.000000

Table 3.7. Results from SUR, Equation (3.10)

Systematic Risk		**Day of the event coefficient**		**Four days after the event**	
	Coefficient		**Coefficient**		**Coefficient**
β1,syy	0.45237	δsyy	-0.0033	ρsyy	-0.0022
	(0.0009)		(0.7786)		(0.7062)
β1,appb	0.8133	δappb	-0.0079	ρ,appb	0.0061
	(0.0276)		(0.8029)		(0.7066)
β1,dri	0.77021)	δdri	-0.0042	ρdri	-0.0068
	(0)		(0.7364)		(0.2878)
β1,eat	0.93482	δeat	-0.0173	ρeat	(0.00131
	(0)		(0.1633)		(0.8365)
β1,osi	1.16961	δosi	0.0042	ρosi	0.00142
	(0)		(0.7445)		(0.8299)
β1,rmk	0.39606	δrmk	-0.0091	ρrmk	-0.009
	(0.0034)		(0.4322)		(0.1291)
β1,pfgc	0.35372	δpfgc	0.07522	ρpfgc	0.00149
	(0.1614)		(0.0005)		(0.8934)
β1,suv	0.83301	δsuv	-0.0072	ρsuv	0.00233
	(0)		(0.5395)		(0.6971)
β1,aho	1.4204	δaho	-0.0006	ρaho	-0.0046
	(0)		(0.9739)		(0.6252)

Table 3.8. Residual Correlation Matrix of System 3.10

	SYY	APPB	DRI	EAT	OSI	RMK	PFGC	SUV	AHO
SYY	1	-0.01571	0.136911	0.076015	0.223594	-0.04291	0.070412	0.100426	-0.05549
APPB	-0.01571	1	0.115614	0.190761	0.139936	0.025557	0.021789	-0.02082	-0.04855
DRI	0.136911	0.115614	1	0.307202	0.338036	0.192727	0.180433	0.014072	-0.06258
EAT	0.076015	0.190761	0.307202	1	0.412702	0.184744	0.006433	-0.09462	0.029822
OSI	0.223594	0.139936	0.338036	0.412702	1	0.01363	0.157645	-0.12459	-0.13532
RMK	-0.04291	0.025557	0.192727	0.184744	0.01363	1	0.074749	-0.06717	-0.04936
PFGC	0.070412	0.021789	0.180433	0.006433	0.157645	0.074749	1	0.189165	-0.0078
SUV	0.100426	-0.02082	0.014072	-0.09462	-0.12459	-0.06717	0.189165	1	0.064932
AHO	-0.05549	-0.04855	-0.06258	0.029822	-0.13532	-0.04936	-0.0078	0.064932	1

Variable definitions are found in Table 3.1

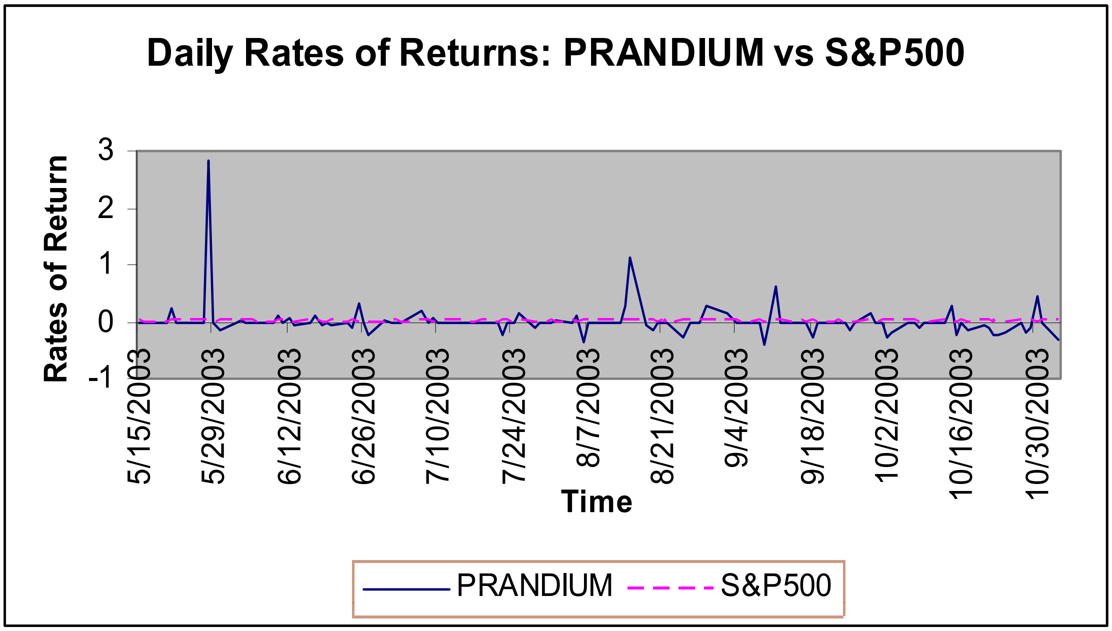

Figure 3.1. Daily Rates of Return: Prandium vs S&P

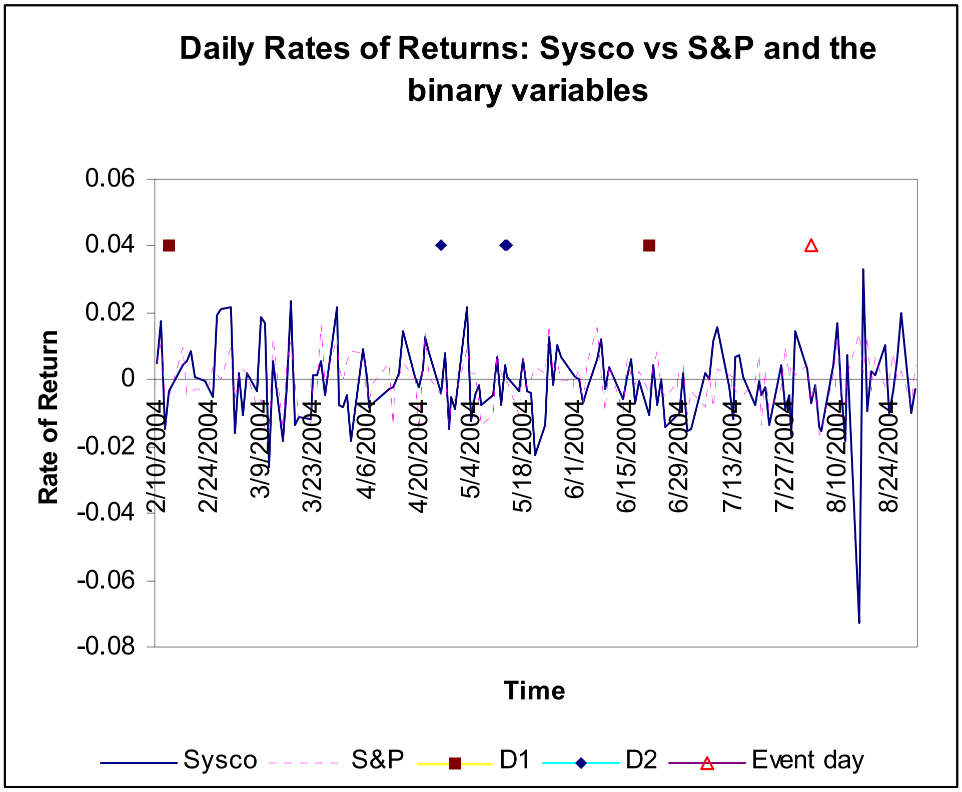

Figure 3.2. Daily Rates of Return: Sysco vs S&P

D1 is Sysco's earnings news day
D2 is Sysco's acquisitions news day
Event days is the day that the event took place (August 3rd, 2004)

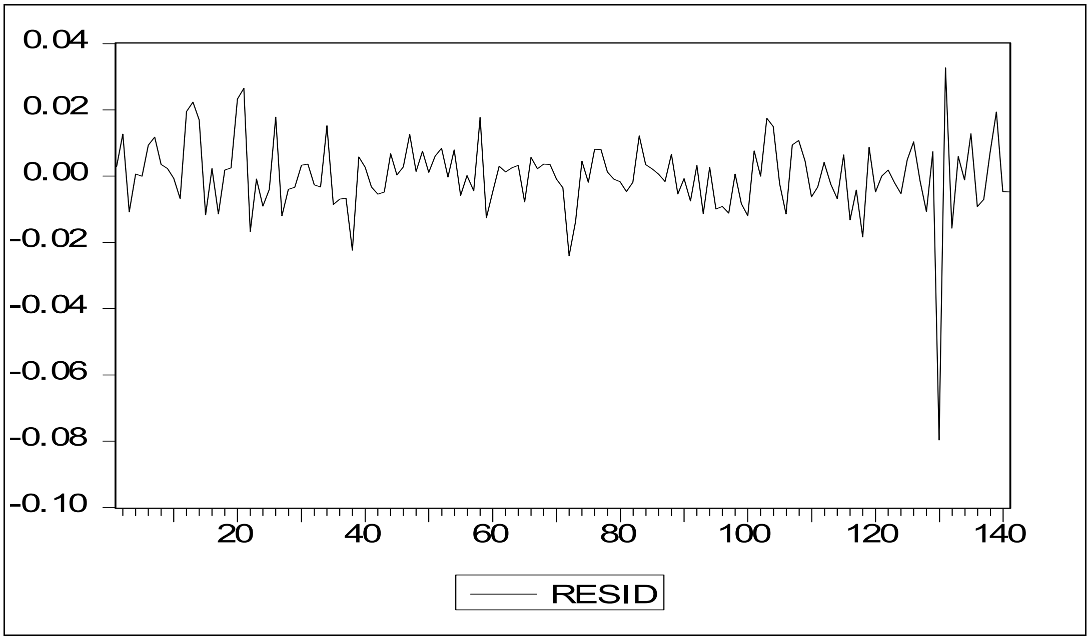

Figure 3.3. Residuals for GARCH Specification

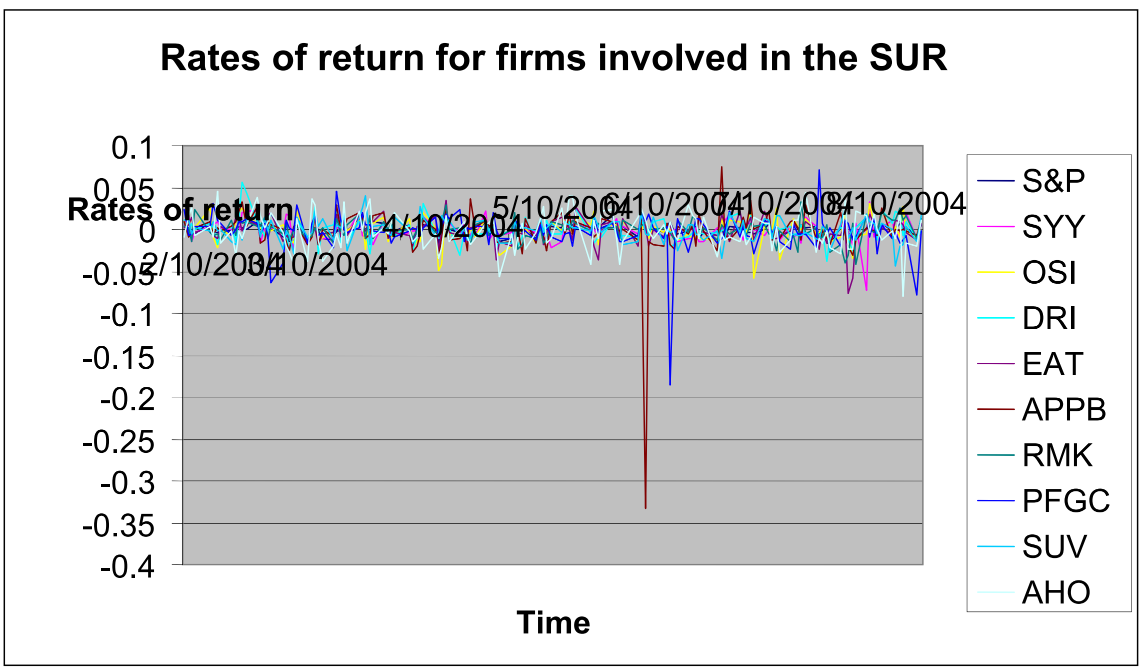

Figure 3.4. Daily Rates of Returns for Food Service and Restaurant Firms

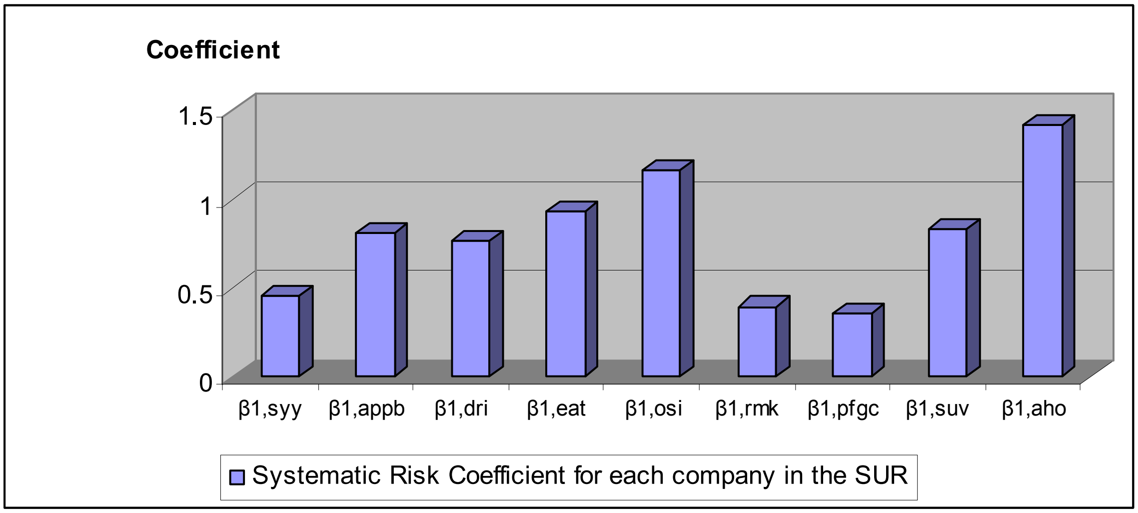

Figure 3.5. Systematic Risk Coefficient for Sysco's SUR (10)

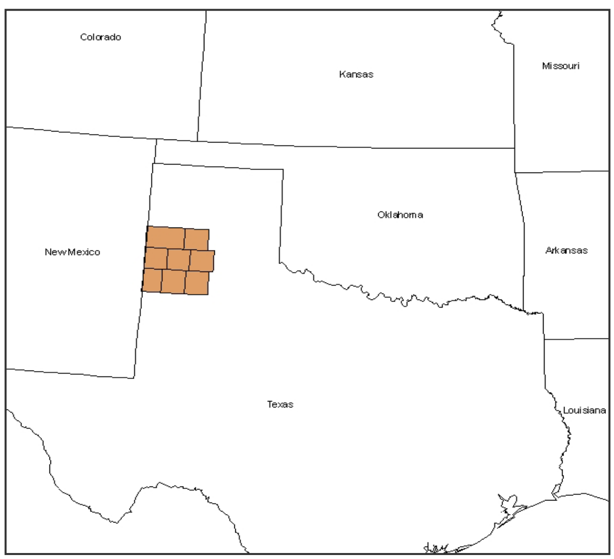

Figure 4.1. Area of Study

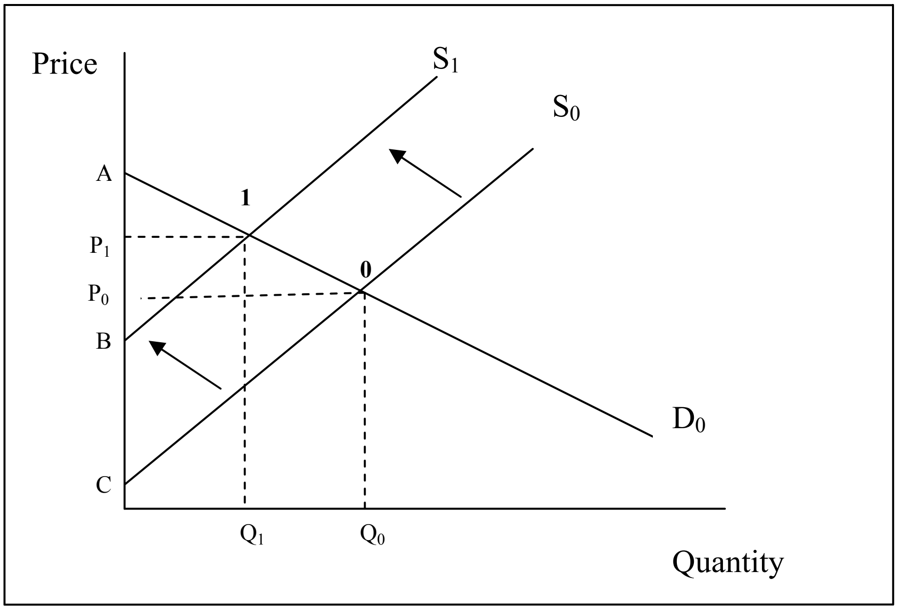

Figure 4.2. Supply Contraction as a Consequence of a Disease Outbreak and No Changes in Preferences

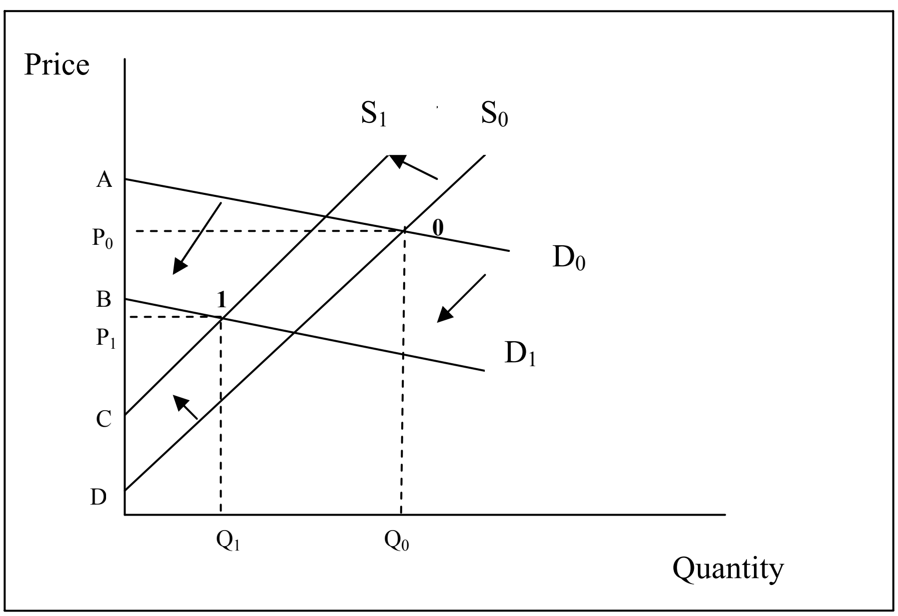

Figure 4.3. Supply and Demand Contraction as a Consequence of a Disease Outbreak and Changes in Preferences

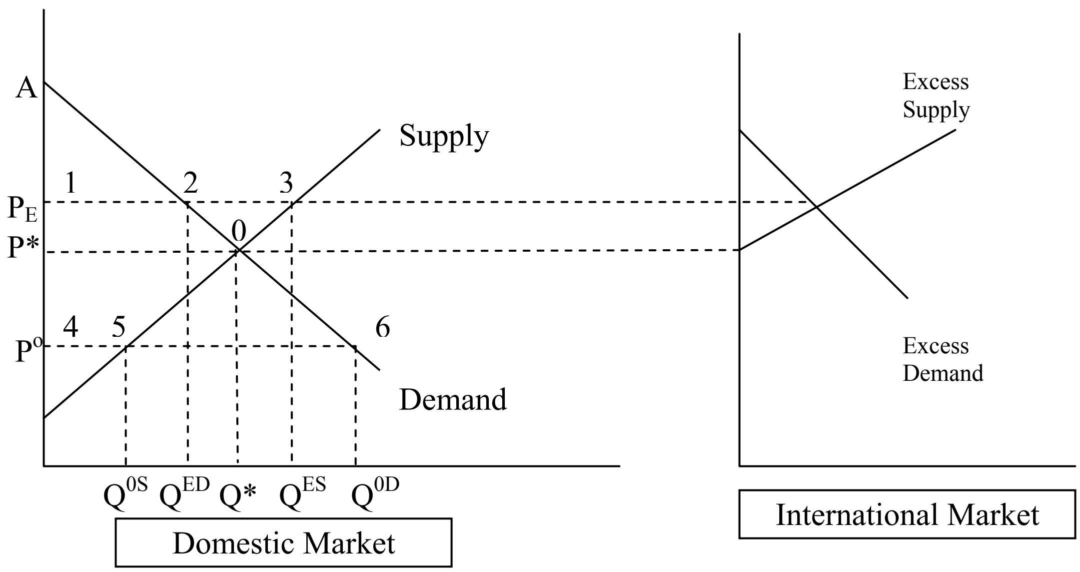

Figure 4.4. Domestic and International Markets Before and After an Outbreak

Source: Schoenbaun and Disney (2003).

Supplemental Information Relevant to Chapter III

Companies Profiles according to Market Report. [17]

Prandium (PRND) The Prandium name was adopted in April, 1999, not too long after the completion of a merger on October 30, 1998 between Koo Koo Roo, Inc. and Family Restaurants, Inc. The predecessor company, Family Restaurants, Inc. ("FRI") was incorporated in 1986. Prandium was the holder of Chi-Chi's restaurants.

Sysco Corporation (SYY). This group's principal activities are to market and distribute food and related products to the foodservice industry. The group's products and services are provided to restaurants, healthcare and educational facilities, lodging establishments, other foodservice; they have around 390,000 customers. The other segments include specialty produce, custom-cut meat, Asian cuisine foodservice, and lodging industry products segments. The group's specialty produce companies distribute fresh produce and, on a limited basis, other foodservice products. Specialty meat companies distribute

[17] This is the official information that companies provide to all financial institution as is available for free in Yahoo, e-trade, The New Tork Times and CNN Money.

custom-cut fresh steaks, other meat, seafood, and poultry. As of July 2, 2005, the group operated 170 facilities throughout the United States and Canada.

Prandium publicly traded competitors:

Applebee's International Incorporated (APPB). This group's principal activity is to develop, franchise, and operate casual dining restaurants under the name Applebee's Neighborhood Grill and Bar. The restaurants feature a broad selection of entrees, including beef, chicken, pork, seafood, and pasta items prepared in a variety of cuisines, as well as appetizers, salads, sandwiches, specialty drinks and desserts. The restaurant is designed as an attractive, friendly neighborhood establishment featuring moderately-priced quality food items, table service, and a comfortable atmosphere. These restaurants are located in free-standing buildings, end caps of strip shopping centers, and shopping malls. As of February 8, 2006, there were 1,813 restaurants operating in 49 states and 14 international countries.

Brinker International, Inc. (EAT). This group's principal activity is to own, operate, develop, and franchise various restaurant concepts. The primary restaurant concepts include: Chili's Grill and Bar, Romano's Macaroni Grill, On The Border Mexican Grill and Cantina, and Maggiano's Little Italy. The group jointly owns and develops the Rockfish Seafood Grill. It operates in the United States, Australia, Canada, Egypt, Great Britain, Germany, Latin America, South America, the Middle East, and Asia. As of December 28, 2005, there were 1,638 company-operated, jointly-developed, and franchised units.

Darden Restaurants, Inc. (DRI). This group's principal activity is to own and operate restaurants. The restaurants are operated under the trademarks: Darden Restaurants (R), Red Lobster (R), Olive Garden (R), Bahama Breeze (R), and Smokey Bones (R) BBQ Sports Bar. As of March 21, 2006, the group owns and operates 1,390 Red Lobster(R), Olive Garden(R), Bahama Breeze(R), Smokey Bones(R) BBQ, and Seasons 52 restaurants.

Outback Steakhouse, Inc. (OSI). This group's principal activity is to develop and operate casual dining restaurants. It offers consumers of different demographic backgrounds an array of dining alternatives suited for differing needs. The restaurants serve dinner only and feature a limited menu of seasoned steaks, prime rib, chops, barbecued ribs, chicken, fish and pasta. As of March 1, 2006, the group operates restaurants including a total of 921 Outback Steakhouses, 203 Carrabba, Italian Grills, 99 Bonefish Grills, 40 Fleming Prime Steakhouse and Wine Bars, 20 Roy, two Lee Roy Selmon, 3 Paul Lee Chinese Kitchens, and 33 Cheeseburger in Paradise restaurants. The operations of the group are carried out in 50 states and 21 countries internationally.

Sysco's publicly traded competitors:

Koninklijke Ahold NV(AHO). The group's principal activity is to provide food primarily through retail trade outlets, along with complementary food service activities. As of December 2002, the group operated or serviced 5,606 stores, including 790 franchise stores and 450 associated stores, with the majority of the franchise stores & associated stores located in The Netherlands. The store format primarily used by the group is the supermarket, along with operating or servicing hypermarkets, discount stores, specialty stores, cash and carry stores and convenience stores, operating primarily in Europe and the United States, with some operations in Latin America and Asia Pacific. Some stores operated by the group include Albert Heijn, Stop & Shop, Giant-Landover and Giant Carlisle.

Aramark Corporation (RMK). The Group's principal activity is to provide managed services to business, educational, healthcare and governmental institutions and sports, entertainment and recreational facilities. It operates in two segments: Food and Support Services and Uniform and Career Apparel. The Food and Support Services segment provides food, refreshment, specialized dietary and support services, including facility maintenance and housekeeping. The Uniform and Career Apparel segment includes the rental, sale, cleaning, maintenance delivery of personalized uniform and career apparel. It also includes direct marketing of personalized uniform and career apparel, public safety equipment and accessories. The Group has International operations in Belgium, Canada, Chile, China, the Czech Republic, Germany, Hungary, Ireland, Japan, Korea, Mexico, Spain and the United Kingdom.

Performance Food Group Company (PFGC) and its subsidiaries engage in the marketing and distribution of brand food and nonfood products to various customers in the foodservice industry primarily in the United States. These products include entrees, canned and dry groceries, frozen foods, refrigerated and dairy products, paper products and cleaning supplies, produce, restaurant equipment, and other supplies. The company operates through two segments, Broadline Foodservice Distribution (Broadline); and Customized Foodservice Distribution (Customized). The Broadline segment markets and distributes national and proprietary brand food and nonfood products to street and chain customers through its 19 Broadline distribution facilities in the eastern, midwestern, northeastern, southern, and southeastern United States. The Customized segment focuses on serving casual and family dining chain restaurants in the United States. It serves 14 restaurant chains nationwide and 3 restaurant chains internationally. The company primarily serves independent restaurants, hotels, cafeterias, schools, healthcare facilities, and other institutional customers, as well as multi-unit or chain customers, such as regional and national family, casual dining, quick-service restaurants, and other institutional customers. Performance Food Group was founded in 1925 and is headquartered in Lebanon, Tennessee.

SUPERVALU, INC. (SVU) operates as a grocery company in the United States. It offers various food and nonfood products, including groceries, meats, dairy products, frozen foods, deli, bakery, fresh fruits and vegetables, health and beauty aids, general merchandise, seasonal items, and tobacco products. The company conducts its retail operations under three retail food store formats: extreme value stores, price superstores, and supermarkets. As of January 11, 2006, SUPERVALU had 1,546 retail grocery locations. In addition, it provides food distribution and related logistics services, including warehouse management, transportation, procurement, contract manufacturing, and logistics engineering and management services for the retail grocery channel. The company's customers include single and multiple grocery store independent operators, regional and national chains, mass merchants, and the military. SUPERVALU was founded in 1871 and is headquartered in Minneapolis, Minnesota.

APPENDIX C

Table 4.1. Farm Types, Descriptions, and Composition from the Epidemiologic Model

Farm Type (t)	Farm Description (f)	Composition by type of animals (t)
1	Beef Grazing	Clave steers, Calve heifers, Yearling steer, Yearling heifers, Beef cow, Milk cow and Bull
2	Dairy	Clave steers, Calve heifers, Yearling steer, Yearling heifers, Beef cow, Milk cow and Bull
3	Pig	Sows Boars Male piglet Female piglet Male wean Female wean
4	Sheep	Ewes, Rams, Wlms, Elms, Wlms yearling and Elms yearling
5	Mixed (beef and sheep)	Clave steers, Calve heifers, Yearling steer, Yearling heifers, Beef cow, Milk cow and Bull Ewes, Rams, Wlms, Elms, Wlms yearling and Elms yearling
6	Backyard	Clave steers, Calve heifers, Yearling steer, Yearling heifers, Beef cow, Milk cow and Bull
7	Feedlot (beef)	Clave steers, Calve heifers, Yearling steer, Yearling heifers, Beef cow, Milk cow and Bull

Table 4.2. Surveillance Cost per Animal

Item	Price
Vaccination	6
Disposal	11*
Euthanasia	5.5

SOURCE: Schoenbaun (2003)

Table 4.3. Strategies

Strategy	Description
1	Quarantine, surveillance, and slaughter latent, immune, or infected herds
2	Quarantine, surveillance, and slaughter herds under any of these statuses: latent, immune, infected, or dangerous contacts
3	Quarantine, surveillance, and slaughter herds under any of these statuses: latent, immune, infected, or contiguous herds
4	Quarantine, surveillance, and slaughter latent, immune, or infected and perform ring vaccination
5	Quarantine, surveillance, and slaughter latent, immune, or infected herds and perform targeted vaccination

Table 4.4. Summary of Control Options for the Five Different Strategies

Strategy	Herds in quarantine	Infected herds	Herds under surveillance	Total number of visits	Total animals vaccinated	Dangerous contact Herds	Slaughtered herds
1	3398	66	145	478	0	0	66
2	4075	71	1442	7002	0	206	277
3	3650	68	107	267	0	0	554
4	1944	46	82	276	2440	0	1260
5	2621	64	101	279	2394	0	1253

Table 4.5. Composition of Herd as a Percentage of the Total Herd for Each Type of Farm

Type of Animal	Grazing	Dairy	Pig	Sheep	Mixed	Backyard	Feedlot
Clave steers	17.00%	5.00%	0.00%	0.00%	15.00%	25.00%	25.00%
Calve heifers	17.00%	5.00%	0.00%	0.00%	10.00%	24.00%	15.00%
Yearling steer	11.00%	5.00%	0.00%	0.00%	20.00%	10.00%	35.00%
Yearling heifer	11.00%	10.00%	0.00%	0.00%	15.00%	10.00%	25.00%
Beef cow	42.00%	0.00%	0.00%	0.00%	7.00%	30.00%	0.00%
Milk cow	0.00%	74.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bull	2.00%	1.00%	0.00%	0.00%	3.00%	1.00%	0.00%
Ewes (adult)	0.00%	0.00%	0.00%	31.00%	15.00%	0.00%	0.00%
Rams (adult)	0.00%	0.00%	0.00%	1.00%	15.00%	0.00%	0.00%
Wether	0.00%	0.00%	0.00%	23.00%	0.00%	0.00%	0.00%
lamb	0.00%	0.00%	0.00%	23.00%	0.00%	0.00%	0.00%
Wether yearling	0.00%	0.00%	0.00%	11.00%	0.00%	0.00%	0.00%
Ewe yearling	0.00%	0.00%	0.00%	11.00%	0.00%	0.00%	0.00%
Sows	0.00%	0.00%	10.00%	0.00%	0.00%	0.00%	0.00%
Boars	0.00%	0.00%	1.00%	0.00%	0.00%	0.00%	0.00%
Male piglet	0.00%	0.00%	30.00%	0.00%	0.00%	0.00%	0.00%
Female piglet	0.00%	0.00%	30.00%	0.00%	0.00%	0.00%	0.00%
Male wean	0.00%	0.00%	15.00%	0.00%	0.00%	0.00%	0.00%
Female wean	0.00%	0.00%	14.00%	0.00%	0.00%	0.00%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Note: The first column describes all types of animals involved in the study. The next seven columns show the animal composition in each different types of farm. This composition is an average of the types of animals a farm has through a year.

Table 4.6. Animal Prices

Animal type	Average Weight	Price in cwt	Price per head
Clave steers	300	150	411
Calve heifers	300	130	411
Yearling steer	700	115	693
Yearling heifer	700	120	693
Beef cow	1200	100	1138
Milk cow	1150	600	1850
Bull		650	700
Ewes (adult)	160	56	56
Rams (adult)	230	56	70
Wether	90	77.77778	70
Lamb	80	72.5	58
Wether yearling	60	116.6667	70
Ewe yearling	50	116	58
Sows	230	37	85
Boars	229	42	96
Male piglet	143	42	60
Female piglet	143	42	60
Male wean	119	42	50
Female wean	119	42	50

Source: USDA
a Prices per cwt
b Prices per head

Table 4.7. Surveillance Costs per Herds

Cost	Small Herds	Medium Herds	Large Herd
Appraisal	300	400	500
Cleaning	5000	7000	10000
Testing	150	200	400
Visit	50	75	100

SOURCE: Schoenbaun (2003)
Small herds contain <100 animals
Medium herds contain 100-450
Large herds contain > 450

Table 4.8. Calculations Based on Strategy Types

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5
Total Market Value Loss	$66,797,640	$123,958,600	$150,168,100	$379,825,300	$153,450,300
Total Foregone Income	$1,388,970	$5,282,730	$10,532,700	$24,068,970	$23,141,430
Total Welfare Slaughter	$38,597,870	$37,451,065	$37,223,990	$8,504,475	$31,579,075
Total Direct Costs	$106,784,480	$166,692,395	$197,924,790	$412,398,745	$208,170,805
Total Slaughter Costs	$2,395,971	$5,185,351	$7,480,873	$18,301,910	$11,124,790
Surveilance	$35,575	$317,100	$26,825	$20,900	$25,650
Vaccination	$0	$0	$0	$3,529,154	$843,508
Total Extra Expenditures	$2,431,546	$5,502,451	$7,507,698	$21,851,964	$11,993,948
Total Indirect Costs	$5,670,000	$5,670,000	$5,670,000	$5,670,000	$5,670,000
Total Costs	$114,886,026	$177,864,846	$211,102,488	$439,920,709	$225,834,753

APPENDIX D

PROGRAM

```
*******************************************************************
*An Economic Cost Module Program in GAMS                          *
*This program aplies the Conceptual Economic Model to an FMD hypotetical   *
*outbreak. An Epidemiologic model's output is used as one of the inputs    *
*and data sources for this program. The Epi model comes from the FAZD Center  *
*at Texas A&M.                                                    *
*                                                                 *
*Pablo Sherwell (main programmer) and Levan Elbakidze             *
*Texas A&M University                                             *
*******************************************************************

*First, define each herd by (id)
set id
 /100*17472/;

**VARIABLES THAT ENTER FROM THE EPI MODEL**
*************************************************
*These are the variables we get from the Epi model and are asociated with each
*herd (id).
*Please see definitions below the variables

set inputfield
 /STRATEGY
CALCACRES
CAT_NUM
TYPE
FARM
ALL_STOCK
CATEGORY
STATUS
Quarantine
D_contact
Infected
CONTACT
SOURCE
HOW
INF_DAY
DX
DAYS_TIL_D
```

DAYS_LEFT_
DAYS_LEFT1
DAYS_LEFT2
WHEN_INF
WHEN_DEAD
DAYS_REP
DAYS_DX
DC
DAYS_DC
CONTIG
SP
SURV
DAYS_TIL_V
N_VISITS
VACC
DAYS_TIL_1
DAYS_TIL_I
XCOORD
YCOORD
DIST
PROXIMITY
BEARING
AREA
NSP
ZONE
FID_
ACRES
ID_1
CAT_DEN
OID_
CALCACRE_1
ID_12
CAT_NUM_1
TYPE_1
FARM_1
ALL_STOC_1
CATEGORY_1
STATUS_1
CONTACT_1
SOURCE_1
HOW_1
INF_DAY_1
DX_1
DAYS_TIL_2

DAYS_LEF_1
DAYS_LEF_2
DAYS_LEF_3
WHEN_INF_1
WHEN_DEA_1
DAYS_REP_1
DAYS_DX_1
DC_1
DAYS_DC_1
CONTIG_1
SP_1
SURV_1
DAYS_TIL_3
N_VISITS_1
VACC_1
DAYS_TIL_4
DAYS_TIL_5
XCOORD_1
YCOORD_1
DIST_1
PROXIMIT_1
BEARING_1
AREA_1
NSP_1
ZONE_1
Quarzone/;

****
DEFINITIONS of Relevant Variables
****
*STRATEGY: Type of Strategy used (1…n)-So far we have 5.

*	Strategy 1 = infected herd slaughter
*	Strategy 2 = infected herd slaughter + dangerous contact slaughter
*	Strategy 3 = infected herd slaughter + contiguous herd slaughter
*	Strategy 4 = infected herd slaughter + ring vaccination
*	Strategy 5 = infected herd slaughter + targeted vaccination
*	(herd types 1, 2 and 7 only)

*CALCACRES: Size of premise in Acres

*CAT_NUM : Number of heads per ID herd

*TYPE = Type of herds

* 1 = Beef
* 2 = dairy
* 3 = sheep
* 4 = pig
* 5 = mixed animal (beef/sheep)
* 6 = backyard <10
* 7 = feedlot

*FARM: Farm type. Same as previous.

*ALL_STOCK: Number of animals (except for type 5 = (Beef + Sheep).

*ALL_STOCK and CAT_NUM = Sheep.

*CATEGORY: General variable to characterize the risk of exposure and spread of
* infection which would use a user defined scale and set of rules rather *
* than premise specific data.

*STATUS
* 0 = Susceptible: able to be infected.
* 1 = Latent: infected but not yet infectious (no shedding of virus and therefore not yet actively spreading infection).
* 2 = Infectious: infected and infectious (i.e. animals are shedding virus and infection can be spread).
* 3 = Dead (removed): in the case of FMD this means a herd that has been slaughtered because of the disease. Conceivably, for a disease that has a very high mortality rate this could represent natural consequence of infection.
* 4 = Immune: herd has recovered from disease, is not infectious and cannot be re-infected.

*QUARANTINE: O means the herd was not in the quarantine zone, 1 means the herd *

* was under quarantine

*D_CONTACT (dangerous contact): 0 means the herd was not a dangerous
* contact(dc), 1 means the herd was a dc, -9999 means dc does
* not apply to that particular strategy.

*INFECTED: 0 means the herd was not infected, 1 means the herd was infected.

*CONTACT Herd ID of herds with contact with infected herd

*SOURCE Herd id of source of infectious contact

*HOW w = wind
* c = contact
* s = saleyard

*INF_DAY

* DX Day that the herd was detected

* DC Dangerous Contact: herds that are not showing FMD symptoms but are considered to be high risk because of either: proximity (distance) or potential contact (direct or indirect) with infected herds.

* CONTIG Contiguous: farm has been classified as a contiguous premise. Slaughter of all herds within a given radius of infected herds.

* SP Suspect Premises
* 1 = flagged as suspect
* -2 = herd cleared after surveillance visits. The minus allows for retrospective follow-up (what proportion of SP's were cleared).

*SURV Indicates herd is under surveillance. farm is under surveillance. This constitutes visit(s) by a surveillance team to check for signs of the disease and possibly collect samples.
* 1 = flagged for surveillance
* 2 = herd has been visited at least once
* 3 = herd is due for a visit today
* 4 = herd missed being visited on due date
* -1 = herd has been cleared after 5 negative surveillance visits
* -2 = FMD confirmed during surveillance visit

*DAYS_TIL_V Number of days from flagged until herd was vaccinated

*N_VISITS Number of visits. Number of visits to surveillance herd
* If visits = 5 with no symptoms then herd cleared.

*VACC Herd has been vaccinated
* 1 = Flagged for vaccination
* 2 = Vaccinated

set farmtype /grazing, dairy, sheep, pig, mixed, backyard, feedlot/;
*These are the types of farms used in the Epi model (7 different type of farms)

set animaltype /calst, calhef, yrlgst, yrlhef, bcow, mcow, bull, ewes, rams, wlms, elms, wyrl, eyrl, sows, boars, mpiglet, fpig, mwean, fwean/;

*types of animals in each farmtype (i.e. grazing has (calst calst calhef yrlgst yrlhef bcow cow bull)

*DESCRIPTION
*Each type of farm has different types of animals by age and by sex

*======BEEF FARMS: Grazing, dairy, backyard, feedlot

*Calst = Clave steers (Calst)
*Calhef = calve hefferds (calhef)
*Yrlgst = Yearling steer (yrlgst)
*Yrhef = Yearling hefferd (yrhef)
*bcow = beef cow (cow)
*mcow = milk cow
*bull (bull)

*=======SHEEP FARMS=====
*types of animals for sheep farms: lamb (young),rams (adult male),
*ewes, rams, flms, mlms, fyrl, myrl
* ewe (adult female) 160 pounds = $89 dlls per head average
* rams (adult male) 230 pounds = $128
* mlamb (young male) 90 pounds = $ 105
* flamb (young female) 80 pounds = $ 93
* myearling (baby male) 60 pounds = $ 70
* Fyearling (baby female) 50 pounds = $ 58
*Prices in Texas by USDA
*Sheep (adult) = $56 Cwt
*Lamb (young) = $ 117 Cwt
*USDA and http://showcase.netins.net/web/sam/ccidf.htm

*=======PIG FARMS=======
*types of animals in [ig farms: hog, sow, boar, piglets

*Boar - An adult male pig 200-250 punds
* Sow - An adult female pig 180-250 pounds
* Piglet/farrow - A juvenile pig 100-180

```
* Shoat - A young pig between 100 to 180 lb (50 to 90 kg)
* Gilt - An immature female pig
* Barrow - A castrated male pig
* Hog - a domestic or wild adult swine, especially one raised for slaughter because they
fatten quickly; in its original sense it means a castrated boar.
* Swine - Synonym for "pigs" (plural)

*Prices according to USDA
*Sows=$37 Cwt
*Barrows and Gilts = $42 Cwt
*Hogs=$42 cwt

*Average Prices per head
*Sows $85
*Boar $96
*Piglet $60
*shoat $50

*=====================

set carcass /burial, incineration, composting, rendering/;
set herdsize /smallherd, medherd, largeherd/;
*Herd size is consistent with Diseney (2001): Small herd contain < 100 animals
(smallherd)
*                                 Medium Herds 100-450 animals (medherd)
*                                 Large herds > 450 animals (largeherds)

*EpiData is the output table we obtained from the Epi model table of results
parameter EpiData(id, inputfield);
$call 'Gdxxrw results1_econstr3.xls Output=EpiData.gdx par=EpiData Rng=a1 cdim=1
rdim=1';
$GDXin  EpiData
$load   EpiData

*PremiseDescription will capture the EpiData. This is usefull for later computation
leaving EpiData intact
parameter PremiseDescription(id, inputfield);

*Cattle status: to account for the status of a particular ID cattle (i.e. 0 = susceptible; 1 =
latent; 2 = infected; 3 = immune; 4 = dead)
parameter Cattlestatus(id, inputfield);
PremiseDescription(id, inputfield) = EpiData(id, inputfield);
Cattlestatus(id, inputfield) = EpiData(id, inputfield);*Costs of animals in dollars
```

parameter animalcost(animaltype) /calst 411, calhef 411, yrlgst 693, yrlhef 693, bcow 1138, mcow 1850, bull 700, ewes 56.4, rams 70, wlms 105, elms 93, wyrl 70, eyrl 58, sows 85, boars 96, mpiglet 60, fpig 60, mwean 50, fwean 50/;

*Real costs:
*The costs were obtained from the USDA, NASS. Agricultural Prices (2006)
*The price for bovine animals are calculated using average weight.
*Calves average weight = 300 pounds
*Yearlings av weight = 700 pounds
*Av cow weight = 1150

*parameter animalcost(animaltype) /calst 150, calhef 130, yrlgst 115, yrlhef 120, cow 600, bull 650/;
*This data comes from Amarillo live stock auction 2005 (USDA Data)
*In APHIS Carc Disposalthe FED Gov will pay only 100 per head as indemnisation. 250 in Disney

*Daily Foregone Income of the farms
parameter foregoneincome(farmtype) /grazing 203, dairy 280, sheep 228, pig 343, mixed 228, backyard 191, feedlot 684/;
*USDA

*Herd Composition
Table composition(farmtype,animaltype)
*Each farm herd has different composition depending on the farm type.
*This numbers come from Doug and are simply estimations.
*For the backyard the estimation is a gueess. It is impossible to know the
*composition of backyards. They vary across each of them.

	calst	calhef	yrlgst	yrlhef	bcow	mcow	bull	ewes	rams	wlms	elms	wyrl	eyrl	sows	boars	mpiglet	fpig	mwean	fwean
grazing	0.17	0.17	0.11	0.11	0.42	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0
dairy	0.17	0.17	0.11	0.11	0	0.43	0.01	0	0	0	0	0	0	0	0	0	0	0	0
pig	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.01	0.3	0.3	0.15	.14
sheep	0	0	0	0	0	0	0	0.31	0.01	0.23	0.23	0.11	0.11	0	0	0	0	0	0
mixed	0.10	0.10	0.1	0.1	0.30	0	0.01	0.03	0.01	0.02	0.02	0.01	0.01	0	0	0	0	0	0
backyard	0.25	0.24	0.1	0.1	0.3	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Feedlot	0.25	0.15	0.35	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 ;

```
*PremiseType
parameter premisetype(farmtype) premisetype descrition
*If FarmType = 1 then feedlot >=10 heads per ID
*If FarmType= 6 backyard < 10 heads
  /Grazing 1
  dairy 2
  sheep 3
  pig 4
  mixed 5
  backyard 6
  feedlot 7/;


****************************************************************
*DESCRIPTION OF MAYOR COST VARIABLES FOR THE FMD MODEL
*Based on Disney (2001) he uses USDA-APHIS FMD Guideline
****************************************************************
*SLAUGHTER COSTS:
*+++++++++++++++

*Slaughter costs are divided in appraisal, euthanasia, carcass disposal and cleaning

parameter costappraisal(herdsize) per herd dependind on herd size
        /smallherd 300
        medherd 400
        largeherd 500/;

*Cost of Euthanasia per animal 5.5 dollars (regardless of size)
scalar costeuthanasia;
costeuthanasia = 5.5;

*Cost of indemnification per head 250 (which we are not using so far)

parameter costdisposal(herdsize) per animal depending on herd size
        /smallherd 11
         medherd   11
        largeherd  12/;

parameter costcleaning(herdsize) (this includes celaning and disinfection) per herd
depending on herd size
        /smallherd 5000
         medherd   7000
        largeherd  10000/;
```

```
*****************************************************************
*SURVEILANCE COST*
*++++++++++++++++
*Twice a week visits on 15km radius during 30 days for sucept herds

parameter costtest(herdsize) per herd depending on herd size
        /smallherd 150
         medherd   200
        largeherd  400/;

parameter costvisit(herdsize) per herd
         /smallherd  50
          medherd    75
         largeherd  100/;

********************************************************************
*VACCINATION COSTS*
*+++++++++++++++++

scalar vaccinecost;
vaccinecost = 6;
*$6 dlls per head
*This number is from Disney

parameter vaccinecostfix(herdsize)
        /smallherd 300
        medherd    500
        largeherd  800/;

*END OF COST VARIABLES
*********************************************************************

parameter herdsizedefinition(herdsize)
        /smallherd 100
        medherd 450
        largeherd 450/;
*Herd size is consistent with Diseney (2001): Small herd contain < 100 animals
(smallherd)
*                                 Medium Herds 100-450 animals (medherd)
*                                 Large herds > 450 animals (largeherds)

*bring the original

set link(id,farmtype, herdsize);
```

```
 link(id,farmtype, "smallherd")$(premisedescription(id,"type")= premisetype(farmtype)
    and (premisedescription (id,"cat_num") lt herdsizedefinition("smallherd")))=yes;
 link(id,farmtype, "medherd")$(premisedescription(id,"type")= premisetype(farmtype)
    and (premisedescription (id,"cat_num") le herdsizedefinition("medherd"))
    and (premisedescription (id,"cat_num") ge herdsizedefinition("smallherd")))=yes;
 link(id,farmtype, "largeherd")$(premisedescription(id,"type")= premisetype(farmtype)
    and (premisedescription (id,"cat_num") gt herdsizedefinition("largeherd")))=yes;
******
*Segregating Mix Farms
******


******************
*CALCULATION COSTS*
******************
*COST IS Broken into two categories: lostvalue market, slaughter cost, surveillance cost
and vaccination cost
*lost value relates to the market lost value

*=======LOSS Market value is calculated by type of farm
*Lost market value for grazing cattle farms

scalar lostvalmkgrazing;

  lostvalmkgrazing= sum[(link(id,farmtype, herdsize), animaltype),
premiseDescription(id, "CAT_NUM") $((Cattlestatus(id, "status") gt 0) and
(cattlestatus(id,"type") eq 1))
            *(Composition(farmtype,animaltype))*animalcost(animaltype)];

*=================================================================
*Lost market value for dairy farms
scalar lostvalmkdairy;

  lostvalmkdairy= sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") gt 0) and (cattlestatus(id,"type") eq 2))
            *(Composition(farmtype,animaltype))*animalcost(animaltype)];

*=================================================================
*Lost market value for sheep farms
scalar lostvalmksheep;

  lostvalmksheep= sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") gt 0) and (cattlestatus(id,"type") eq 3))
            *(Composition(farmtype,animaltype))*animalcost(animaltype)];
```

```
*==================================================================
*Lost market value for pig farms
scalar lostvalmkpigs;

lostvalmkpigs= sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
          "CAT_NUM") $((Cattlestatus(id, "status") gt 0) and cattlestatus(id,"type") eq 4))
          *(Composition(farmtype,animaltype))*animalcost(animaltype)];
*==================================================================
*Lost market value for mix farms (beef and sheep)
scalar lostvalmkmix;

 lostvalmkmix= sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
         "ALL_STOCK") $((Cattlestatus(id, "status") gt 0) and (cattlestatus(id,"type") eq
         5))*(Composition(farmtype,animaltype))*animalcost(animaltype)];

*==================================================================
*Lost market value for backyard little farms (less than 10 heads)

scalar lostvalmkbackyard;

  lostvalmkbackyard= sum[(link(id,farmtype, herdsize), animaltype),
                  premiseDescription(id, "CAT_NUM") $((Cattlestatus(id, "status") gt 0)
                  and (cattlestatus(id,"type") eq
                  6))*(Composition(farmtype,animaltype))*animalcost(animaltype)];
*==================================================================
*Lost market value for feedlot

scalar lostvalmkfeedlot;

lostvalmkfeedlot= sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
                  "CAT_NUM") $((Cattlestatus(id, "status") gt 0) and
                  (cattlestatus(id,"type") eq 7) *(Composition(farmtype,animaltype))
                  *animalcost(animaltype)];
*==================================================================
*total market value loss (sum of all lost market value costs)

scalar totalmarketloss;

  totalmarketloss= lostvalmkgrazing + lostvalmksheep + lostvalmkdairy + lostvalmkpigs
+ lostvalmkmix + lostvalmkbackyard + lostvalmkfeedlot;

*==================================================================
*FOREGONE INCOME FOR 90 Days
*foregone income fpr beef grazing
```

```
scalar foregoneincomebeef;

foregoneincomebeef=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 1)), foregoneincome(farmtype)*90];
*=============================================================

scalar foregoneincomedairy;

foregoneincomedairy=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 2)), foregoneincome(farmtype)*90];
*=============================================================
scalar foregoneincomesheep;

foregoneincomesheep=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 3)), foregoneincome(farmtype)*90];
*=============================================================

scalar foregoneincomepig;

foregoneincomepig=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 4)), foregoneincome(farmtype)*90];
*=============================================================

scalar foregoneincomemix;

foregoneincomemix=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 5)), foregoneincome(farmtype)*90];
*=============================================================

scalar foregoneincomeback;

foregoneincomeback=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 6)), foregoneincome(farmtype)*90];
*=============================================================

scalar foregoneincomefeed;

foregoneincomefeed=sum[(link(id,farmtype,herdsize))$((Cattlestatus(id, "status") gt 0)
and (cattlestatus(id,"type") eq 7)), foregoneincome(farmtype)*90];

*=============================================================
*Total Foregone income

scalar tforegoneincome;
```

```
tforegoneincome= foregoneincomebeef+foregoneincomedairy+foregoneincomesheep
+foregoneincomepig+foregoneincomemix+foregoneincomeback+foregoneincomefeed;
*=====================================================================

*cost of slaughter - appraisal, euthanesia, disposal, cleaning
scalar costslaughter;

 costslaughter=sum[(link(id,farmtype,herdsize))$(Cattlestatus(id, "status") gt 0),
(premiseDescription(id, "CAT_NUM") *(costeuthanasia + costdisposal(herdsize))
                + costappraisal(herdsize)+costcleaning(herdsize)) ];
*=====================================================================

*cost of surveilance (tests + visits)
*From the SURV variable
scalar costsurv;

costsurv = sum[(link(id,farmtype,herdsize))$(Cattlestatus(id, "surv") ne 0),
costtest(herdsize)+ costvisit(herdsize) ];

*=====================================================================
scalar costsvaccination;

costsvaccination=sum[(link(id,farmtype,herdsize))$(premiseDescription(id, "vacc") gt
0), premiseDescription(id, "cat_num")*vaccinecost + vaccinecostfix(herdsize)];

*=====================================================================
* WELFARE SLAUGHTER COSTS:
*========================

*Welfer cost for Grazing cattle farms
scalar welfaregrazing;

welfaregrazing=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 1))
*(Composition(farmtype,animaltype))*animalcost(animaltype)];

*=====================================================================
*Welfer cost for dairy farms

scalar welfaredairy;
```

```
welfaredairy=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 2))
*(Composition(farmtype,animaltype))*animalcost(animaltype)];

*==============================================================
*Welfer cost for sheep
scalar welfaresheep;

  welfaresheep=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 3))
          *(Composition(farmtype,animaltype))*animalcost(animaltype)];
*==============================================================
*Welfer cost for pig farms
scalar welfarepig;

  welfarepig=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 4))
          *(Composition(farmtype,animaltype))*animalcost(animaltype)];

*==============================================================
*Welfer cost for mixed farms (cattle and sheep)
scalar welfaremixed;

  welfaremixed=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 5))
          *(Composition(farmtype,animaltype))*animalcost(animaltype)];
*==============================================================
*Welfer cost for backyard farms
scalar welfareback;

  welfareback=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 6))
          *(Composition(farmtype,animaltype))*animalcost(animaltype)];
*==============================================================
*Welfer cost for feedlot operations.
scalar welfarefeedlot;
```

```
  welfarefeedlot=sum[(link(id,farmtype, herdsize), animaltype), premiseDescription(id,
"CAT_NUM") $((Cattlestatus(id, "status") eq 0) and (Cattlestatus(id, "Quarantine") eq
1) and (cattlestatus(id,"type") eq 7))
           *(Composition(farmtype,animaltype))*animalcost(animaltype)];
*Total welfare cost
scalar totwelfare;

  totwelfare=welfaregrazing + welfaredairy + welfaresheep + welfarepig +
welfaremixed + welfareback + welfarefeedlot

*DISPLAY THE RESULTS
*---------------------------------*
display  PremiseDescription;
display lostvalmkgrazing;
display lostvalmksheep;
display lostvalmkdairy;
display lostvalmkpigs;
display lostvalmkmix;
display  lostvalmkbackyard;
display  lostvalmkfeedlot;
display totalmarketloss;
display foregoneincomebeef;
display foregoneincomedairy;
display foregoneincomesheep;
display foregoneincomepig;
display foregoneincomemix;
display foregoneincomeback;
display foregoneincomefeed;
display tforegoneincome;
display costslaughter;
display costsurv;
display costsvaccination;
display welfaregrazing;
display welfaredairy;
display welfaresheep ;
display welfarepig;
display welfaremixed;
display welfareback;
display welfarefeedlot;
display totwelfare;

*End of Program
```

VITA

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PUBLICATIONS, WORKING PAPERS AND PRESENTATIONS

Sherwell, P. and Capps, O. “Spatial Asymmetry in Farm-Retail Price Transmission Associated with Fluid Milk Products” Submitted to the *Agribusiness: An International Journal* and Presented at *the American Agricultural Economics Association*, Providence, RI. July, 2005.