

PREDICTING FOOD SAFETY LOSSES IN TURKEY PROCESSING

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ABSTRACT

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Over the past decade, food recalls and microbial outbreaks have cost the meat and poultry industry billions of dollars. The United States Department of Agriculture-Food Safety and Inspection Service (USDA-FSIS) on July 25, 1996, published a final rule for Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP). Firms are faced with the challenge to balance the increasing expenses to decrease food recalls and negative publicity due to foodborne illnesses and maximizing profits.

Empirical evidence suggests that among broilers, eggs, turkeys, and chickens, *Salmonella* contamination of ground turkey is highest at 49.9% prior to PR/HACCP implementation and 26.6% after PR/HACCP implementation. *Salmonella* outbreaks have greatly contributed to the large number of food recalls in the meat and poultry industry, and would suggest that processed turkey constitutes a prime commodity for PR/HACCP intervention analysis.

Value-at-Risk (VaR) is used in this thesis under three alternative scenarios: prior to PR/HACCP implementation, after PR/HACCP implementation, and under more stringent risk management strategies to determine the risk reduction capabilities and performance of PR/HACCP systems. Also, the likelihood ratio and Z tests are used to evaluate the effectiveness of VaR in predicting food safety losses. Finally, this thesis provides firm managers and policy makers with a better understanding about the use of VaR as a risk measurement and management tool for food safety risk.

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CHAPTER 1. INTRODUCTION

Background/Problem Statement

According to the United States Center for Disease Control (CDC), an estimated 76 million foodborne illnesses occur each year in the United States. Of these cases, 325,000 hospitalizations and 5,000 deaths occur each year (Mead et al., 1999). Food Safety and Inspection Services (FSIS)¹ (1996) estimated that approximately 4,000 deaths each year are attributed to contamination in meat and poultry products. The most severe illnesses associated with foodborne pathogens include complications such as septicemia (infection of the blood stream), localized infections of other organs, and spontaneous abortion in pregnant woman (Lindsay, 1997). Two-thirds of these most severe foodborne illnesses may become chronic health problems. Table 1.1 shows the estimates of foodborne illness for selected pathogens. These pathogens have significantly impacted the meat and poultry industry over the past decade, resulting in a number of foodborne illness and deaths.

Over the past decade, food recalls have cost the meat and poultry industry billions of dollars. *E. coli* O157:H7 may have cost the beef industry alone \$2.7 billion in the past 10 years (Kay, 2003). Also, FSIS records of food recalls from 1994-2003 indicate that as much as a \$1.35 billion loss was realized in the turkey industry.

Losses due to food safety risk and microbial outbreak do not only impact the meat and poultry industry; they impact society as a whole. Financial compensation for injuries due to contaminated food products is important because foodborne illness imposes substantial economic costs to society (Buzby, Frenzen, and Rasco, 2001).

¹ FSIS is the branch of the USDA that ensures the safety, wholesomeness, and accurate labeling of meat, poultry, and egg products.

Table 1.1. Estimates of Selected Foodborne Illnesses

Pathogen	Annual cases	Annual deaths	Share foodborne %	Share foodborne from meat and poultry %	Annual cases from meat and poultry	Annual deaths from meat and poultry
<i>Salmonella</i>	800,000-4,000,000	1,000-2,000	87-96	50-75	459,700-2,880,000	435-1,440
<i>E. Coli O157:H7</i>	10,000-20,000	220-541	80	75	6,000-12,000	132-325
<i>Campylobacter jejuni</i>	2,000,000-10,000,000	200-730	55-70	75	825,000-5,250,000	83-383
<i>Listeria monocytogenes</i>	1,118-1,1093	270-510	89-95	50	464-884	115-242

Source: Buzby et al. (1996).

Foodborne illness cases cost \$6.5 billion-\$13.3 billion a year in work loss, doctor's visits, and deaths (Hooker and Teratanavat, 2001). Furthermore, annual medical costs, productivity losses, and costs of premature deaths due to five major foodborne pathogens cost \$6.9 billion (Crutchfield and Roberts, 2000).

Due to the growing number of food recalls and microbial outbreaks, the USDA-FSIS on July 25, 1996, published a final rule for Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP). PR/HACCP is a continuous, comprehensive food safety monitoring system designed to prevent hazards from developing along the production process, thus ensuring a high degree of food safety (Bjerklie, 1992; Karr, Maretzki, and Knabel, 1994). PR/HACCP represents a new approach to food safety in the meat industry because it focuses on prevention of microbial hazards, rather than ex post inspection for contamination (Unnevehr and Jensen, 1998).

According to the FSIS (1996), the following dates for PR/HACCP implementation were adopted:

1. January 26, 1998, for all meat and poultry plants over 500 employees (large plants);
2. January 26, 1999, for plants with 11 to 499 employees (small plants); and
3. January 26, 2000, for plants with up to 10 employees (very small plants).

Goodwin and Shiptsova (2000) noted that, approximately 7,000 inspectors operating from 17 regional USDA-FSIS offices are currently dedicated to PR/HACCP implementation and enforcement. The pathogen reduction regulation was expected to have a major impact on the safety of meat and poultry products and on industry production methods. Crutchfield et al. (1997) estimated that, the benefits of PR/HACCP would range annually from \$1.9-171.8 billion in 1995.

Performance data on PR/HACCP combined with FSIS data from 1998-2002 show a decrease in *Salmonella* prevalence in all classes of products below the baseline prevalence estimates determined prior to PR/HACCP implementation (Rawson, 2003). Table 1.2 shows the decrease in *Salmonella* levels from 1998-2002 for selected meat and poultry products. However, despite the decrease in pathogen levels after the implementation of PR/HACCP, causality between PR/HACCP system and the improvement of health/firm-level benefit is still controversial.

There is a growing concern about the cost of implementing PR/HACCP versus the benefit, especially for small plants. The USDA-FSIS has estimated the benefit of PR/HACCP to be greater than the cost of implementation.

Because PR/HACCP increases the costs of producing meat and poultry products, researchers have suggested USDA's regulations may cause meat and poultry plants to exit at faster rates or enter at slower rates than in the past (Muth et al., 2002). In addition, small

Table 1.2. Decreased *Salmonella* Level for Selected Meat and Poultry Products

Products	Prior to HACCP implementation	After HACCP implementation
Young chickens	20%	10%
Market hogs	8.7%	4.7%
Cows and bulls	2.7%	2.2%
Steer and heifers	1%	0.4%
Ground beef	7.5%	3.2%
Ground chicken	44.6%	19.8%
Ground turkey	49.9%	26.6%

Source: Rawson (2003).

plants in particular would be driven out of the industry because their costs per unit of output would be higher than that for large plants (MacDonald et al., 1996). Firms are faced with the challenge to balance the increasing expenses to decrease food recalls and negative publicity due to foodborne illnesses and maximizing profits. Major players in the industry argue that mandatory PR/HACCP regulations exceed the concept by establishing what they view as impractical, expensive testing regimes and unrealistic standards (Rawson, 2003).

Recent developments in the area of Value-at-Risk (VaR) provide a framework for assisting firm management to predict food safety risks in monetary terms and to evaluate the effectiveness of control measures like PR/HACCP. VaR enables a firm to determine which strategy offers the greatest expected returns at the least expense possible. VaR gives the probability of a portfolio of assets losing a certain amount in a given period at a particular level of confidence. For example, a VaR of \$5 million at a 95% level of confidence indicates that the overall portfolio losses should not exceed \$5 million more than 5% in a given time period. VaR estimates enable firm managers to implement risk management strategies to further reduce or maintain the losses in accordance with the firm's objectives.

Overall, food safety risk and continuous occurrence of microbial outbreak constitute a major challenge for all parties involved in the food supply chain. Food recalls and microbial outbreaks continue to be prevalent in industries where firms now operate under USDA-FSIS approved PR/HACCP. These foodborne illnesses cases have been attributed to inefficient implementation of control measures and difficulties associated with evaluating the benefits of these measures. Food safety managers are faced with the problem of assembling a portfolio of mitigation techniques to obtain some desired level of safety (McDowell et al., 1995). Assisting policy makers and firm managers to effectively assess food safety risk and evaluate the effectiveness of control measures to mitigate these risks are paramount to the United States and to the global food safety system.

Justification of Study

Food safety risk, continuous microbial outbreak and after PR/HACCP implementation are of great concern or importance to plant managers, policy makers, government agencies responsible for public health and consumers. Although, the goal of plant managers, policy makers, and government agencies is to reduce foodborne illness due to pathogenic microorganisms on food products, the benefit of PR/HACCP implementation relative to the cost of implementation is still controversial. The number and size of food recalls have increased dramatically over the last decade. Between 1993 and 1996, the number of meat and poultry Class I² recalls averaged about 24 per year (1.5 million pounds annually). Between 1997 and 2000, Class I recalls averaged 41 per year (24 million pounds annually) (Ollinger and Ballenger, 2003). After 2000, however, there was a decrease in

² Class I recalls involve meat or poultry products that could, especially without cooking to safe temperatures, cause serious illness or death.

food recalls which amounted to less than 100,000 pounds and only few involved more than 1 million pounds of product (Hooker and Teratanavat, 2001).

There have been several studies done using alternative methods to compare the cost of implementing PR/HACCP system to its benefit. For example, Translog profit function was used to evaluate cost of PR/HACCP for small firms that slaughter and process meat. The results suggested that the benefit was 29-62% greater than costs of implementing PR/HACCP for large firms (Nganje, Mazzocco, and McKeith, 1999). Also, Probit model was used to evaluate the benefit of implementing PR/HACCP versus its cost for different firm sizes namely large, small, and very small (Muth et al., 2002). However, there has been limited analysis done to predict the losses a firm may incur at any given time, and the benefits of intervention strategies like PR/HACCP. The VaR methodology provides great prospects to overcome this limitation.

The use of VaR by practitioners in the financial institution is on the rise. VaR is being embraced by corporate risk managers as an important tool in the overall risk management process. In particular, upper-level managers, who may or may not be well versed with statistical analysis, view VaR as an intuitive measure of risk since it concentrates only on adverse outcomes and is usually reported in dollars or returns. In addition, the use of VaR as a risk predicting and measurement tool has several potential applications in agriculture (Manfredo and Leuthold, 2001). Due to the dynamic nature of agriculture and reduction of government programs, there exists a new risky environment in agriculture. Examples of previous studies done using VaR in agriculture context:

1. Manfredo and Leuthold (2001) used VaR to predict market risk and cattle feeding margin;

2. Garci, Roh, and Leuthold (1995) used VaR to simultaneously determined, time varying hedging ratios in the soybean complex; and
3. Tzang, D.N., and R.M. Leuthold (1990) used VaR to determine hedge ratios under inherent risk reduction in a commodity complex.

Description of the Study

VaR is used to predict the monthly losses incurred by a characteristic and small turkey processing plant under three alternative scenarios:

1. Prior to PR/HACCP implementation;
2. After PR/HACCP implementation; and
3. Under more stringent risk management strategies.

In addition, “out-of-sample” testing is used to determine the robustness of VaR in predicting food safety losses under all three alternative scenarios.

VaR models are developed using @Risk software package and stochastic simulation techniques. Secondary data on net processing margins for characteristic turkey processing plant, prior to and after PR/HACCP implementation from 1995-2003, is used for the analysis. Primary data from a small turkey processing plant is also used.

Study Objectives

The goal of this study is to determine the risk reduction capabilities and performance of PR/HACCP systems. More specifically, the three objectives of this study are

1. Determine the risk (firm-level economic loss) reducing impacts of PR/HACCP using VaR. This objective will enable us to simulate firm-level

incentives with PR/HACCP and validate if the observed *Salmonella* reduction levels after PR/HACCP translate to economic gain,

2. Evaluate the effectiveness of VaR in predicting food safety losses incurred by a characteristic and small turkey processing plant, under three alternative scenarios. The likelihood ratio and Z tests are used to evaluate the effectiveness or robustness of VaR estimates, and
3. Help both firm managers and policy makers to better understand the use of VaR as a risk measurement and management tool for food safety risk.

The hypothesis of this thesis is that PR/HACCP implementation significantly reduces firm-level food safety risk and improves profitability.

Thesis Outline

Chapter 2 is a Literature Review of previous work done with VaR and benefit/cost impact studies of PR/HACCP implementation systems. Chapter 3 focuses on the theoretical models of VaR and their limitations. Chapter 4 presents the empirical models and data. Chapter 5 reports and discusses the results. This chapter also suggests how VaR can be used by firm managers to implement better risk management strategies. Finally, Chapter 6 presents the conclusions, policy implications for management, limitations, and recommendations for further studies.

CHAPTER 2. LITERATURE REVIEW

Food safety risks and the occurrence of microbial outbreaks constitute a major challenge for all parties involved in the food supply chain. The growing concern in recent years allowed the USDA-FSIS to pass a final rule for PR/HACCP system implementation in 1996. The objective was to minimize occurrence of microbial outbreak and improve food safety systems along the line of production. However, after PR/HACCP implementation system in January 26, 1998; January 26, 1999; and January 26, 2000 for large, medium, and small firms, respectively, there is still controversy about its effectiveness. The controversy arises from disagreement as to whether PR/HACCP is the best alternative for reducing the occurrence of microbial outbreaks (microbial performances standards are not a zero reduction limit strategy). Also, USDA estimates of societal marginal benefits may have been grossly overstated and cost to the firm understated (Antle, 2000).

Chapter 2 briefly introduces the concept of a PR/HACCP system and how it works. It provides evidence about the benefits and cost of PR/HACCP implementation and discusses empirical studies of PR/HACCP implementation, difficulties associated with measuring the marginal benefit and cost of a PR/HACCP system at the firm-level, and the overall performance of a PR/HACCP system. In addition, the concept of VaR is introduced and its historical application in financial institutions as a risk measurement and management tool is discussed. Furthermore, the advantages and disadvantages of VaR are reviewed; the two major procedures of VaR are presented; the current status of VaR and its application in agricultural economics is reviewed; and on how VaR can be applied to the concept of PR/HACCP or the effectiveness of food safety regulation is discussed.

PR/HACCP System and Its Characteristics

PR/HACCP is defined as a continuous, comprehensive food safety monitoring system designed to prevent hazards from developing along the production process, thus ensuring a high degree of food safety (Bjerklie, 1992; Karr, Maretzki, and Knabel, 1994). There are seven major steps in implementing a PR/HACCP system in order to ensure a high degree of food safety and that end products are wholesome and fit for consumption. They were established in 1992 by the National Advisory Committee on Microbiological Criteria for Food (NACMCF, 1997). They are

1. Hazard analysis: risk assessment hazard identification and exposure assessment. For each step, identify hazard that are likely to cause illness or injury if not prevented and eliminated, or reduce them to an acceptable level. The selection is made by the PR/HACCP team base on Severity (illness, magnitude, and duration) and Likely occurrence (experience, epidemiological data, and information from the technical literature;
2. Determine Critical Control Point (CCP):³ Controls will only relate to safety, not quality;
3. Establish critical limits: risk assessment and dose response. The critical limit refers to the magnitude/size of the hazard that makes very frail to very resistant people ill or hurt. It is a sigmoid dose response distribution. Normally, the government sets this for the most sensitive person, if it is set at all. Pasteurization of 1,000 per gram *Salmonella* is reduced to 1 per 100

³ Critical Control Point is a point or stage during manufacture where it is essential to control (reduce or eliminate) a hazard.

grams. Also, sterilization of 1 clostridium botulinum spore per gram is reduced to 1 per 12 billion grams;

4. Establish procedures to monitor each CCP: Probability that the cook or the customer will detect the out of control condition and discard the food (cook) or not eat it (customer);
5. Establish corrective actions: What is done with food produced out of control by whom and what record is made;
6. Establish record keeping: Documentation of control of the steps; and
7. Establish verification procedures: Verification by the operator that the system is operating according to plan that it is scientifically sound, that all hazards have been identified and if controls are followed, the hazard in the food will be tolerable.

After a brief introduction of the concept and application of PR/HACCP system, it is important to understand the impact of the PR/HACCP system on industry and firm-level benefits and costs. The next section deals with empirical cases of PR/HACCP implementation and the difficulty in measuring the marginal cost and benefit to the firm.

Benefits of Implementing PR/HACCP System

In general, government agencies support the notion that a PR/HACCP system can reduce and control food safety risk and may improve firm's profitability. The FSIS and Food and Drug Administration (FDA) claimed that PR/HACCP has the following advantages over current U.S. food safety regulatory programs:

1. Prevents largely avoidable events to reduce contamination of food from farm to retail;

2. Uses scientific risk assessment for pathogens likely to be associated with each food;
3. Places food safety responsibility clearly on food manufacturers or distributors;
4. Improves food safety practices by setting public health-oriented targets;
5. Fosters scientific and technological innovation by removing regulatory obstacles;
6. Permits more efficient and effective government oversight because the recordkeeping on PR/HACCP sanitation, pathogen testing, and other procedures allows inspectors to better assess safety than spot checks or visual inspection; and
7. Helps food companies compete more effectively in international markets where PR/HACCP requirements are becoming common.

The benefits of PR/HACCP system can be directly evaluated at the firm-level. For example, the potential benefits from implementing PR/HACCP system are (Unnevehr and Roberts, 1996)

1. Longer product shelf life;
2. Access to new, distant markets, including international markets;
3. Greater reliability to consumers; and
4. Reduced produce recalls, defects, and liability.

In monetary terms, the benefits of PR/HACCP should exceed the cost of implementing it. However, the challenge is to quantify the benefits. The benefit of PR/HACCP ranges from \$1.9 billion-\$171.8 billion annually (Crutchfield et al., 1997).

Several studies have shown that food producers adopt PR/HACCP in order to satisfy downstream customers. In addition, firms have incentives for PR/HACCP adoption to prevent loss of reputation and market share should an outbreak occur (Mazzocco, 1996; Henson and Northen, 1998). Furthermore, the adoption of PR/HACCP has enabled firm management to decide on the quality and improvement of end products. It is important to recognize that PR/HACCP is not designed to replace management decisions weighing potential benefits from product qualities against cost, or the value of improved safety versus the costs of achieving it. PR/HACCP facilities improve product safety, but management has discretion to determine what the final product quality will be. These issues enter into the firm's deliberations in determining CCPs and tolerance limits at CCPs (Unnevehr and Jensen, 1998). The overall benefit of PR/HACCP implementation by the firm may improve its profitability and reduce the occurrence of pathogenic microorganisms in the end products. Yet, there is still controversy about its implementation cost.

Cost of Implementing PR/HACCP System

The cost of implementing PR/HACCP differs from firm to firm. PR/HACCP cost has two major components: Implementation costs and operating costs. Implementation costs include three main components:

1. Plan development cost;
2. Training costs; and
3. Material, building, and equipment costs.

Operating costs include three main components:

1. Record keeping costs,

2. USDA verification cost, and
3. Bacteria testing.

Implementation and operating costs are considered fixed and variable costs, respectively.

Fixed or implementation costs are defined as costs that do not vary with production levels. An example of a fixed cost includes expense on equipment or material that has a life span greater than one year. On the other hand, variable or operating costs are defined as costs that vary with the level of production. An example of a variable or operating cost includes expenses on equipment or material that has a life span equal to or less than one year like electricity bills, paper wraps, and boxes. These components are very important in determining the difficulty in measuring the cost effectiveness of PR/HACCP system for different firm sizes (large, medium, and small). PR/HACCP involves a large fixed investment to develop the plan and to train staff. It may also require new capital equipment. These fixed costs mean that there are economies of scale in PR/HACCP. The variable costs are often minor in terms of labor or materials (Unnevehr and Roberts, 1996).

Studies Related to Costs of Implementing PR/HACCP System

There have been studies related to measuring the cost effectiveness of implementing PR/HACCP. The results of these studies indicated that, there is still controversy about how expensive it is to implement PR/HACCP system and how costs compare to benefits for the firm. The cost of maintaining a PR/HACCP system is about 1.1% of total costs, which ranges from about 0.4 cents per pound for poultry to 1.2 cents per pound for beef, or about 0.9 cents per pound on average for meat or poultry (Crutchfield et al., 1997). These results are higher than the FSIS cost estimate of 0.12 cents per pound, but it is close to the estimate

of Antle (2000) of about 1.39 cents per pound and Boland, Peterson, and Fox (2001) of about 0.9 cents per pound.

Because of limited ability to fully capture returns to costly control of product hazard, firms lack incentive to implement controls for food safety (Unnevehr and Jensen, 1998). Because PR/HACCP increases the costs of producing meat and poultry products, researchers have suggested USDA regulations may cause meat and poultry plants to exit at faster rates or enter at slower rates than in the past. In addition, different plant sizes (very small, small, and large) and their entry and exit from 1993-1996 and 1996-2000 are compared in Table 2.1 (Muth et al., 2002).

Table 2.1. Percentage Rates of Entry and Exit of U.S. Federally Inspected Meat Slaughter Plants

PR/HACCP Sizes	Entry Rates (%)		Exit Rates (%)	
	1993-1996	1996-2000	1993-1996	1996-2000
Very Small Plants: (<\$2.5 mil. in sales)	7.8	13.0	12.5	19.9
Small Plants: (10 to 500 employees)	6.6	6.4	16.4	17.0
Large Plants: (> 500 employees)	11.9	0.0	3.4	1.6
Total Plants	7.7	10.3	13.1	17.8

Source: Muth et al. (2002).

Table 2.1 illustrates that very small and small plants are most likely to exit due to higher PR/HACCP implementation costs than large plants. However, this is only one study from several that support or do not support the implementation of a PR/HACCP system.

Another study examined the profitability, output price, and PR/HACCP technology jointly, assuming that small firms in the meat and poultry industry are seeking to maximize profits. This study was based on data from 34 small firms with PR/HACCP systems. The

majority of the firms performed both slaughtering and processing activities. Of the 34 firms, 27 slaughter and process meat, 5 only process, and 2 only slaughter. Table 2.2 shows the results of three profit share equations used in this study to justify the impact of PR/HACCP on the firm's net profit (Nganje, Mazzocco, and Mckeith, 1999).

Table 2.2 shows that the estimated net profits after PR/HACCP implementation are greater than prior to PR/HACCP implementation. Although PR/HACCP expenses are higher for small firms, and the output may not increase significantly, overall, PR/HACCP implementation by small firms is profitable. Profitability for very small firms decreased after they implemented PR/HACCP.

Table 2.2. Estimated Firms Net Profits Prior to and After PR/HACCP Implementation

Sizes	Estimated Coef. Prior PR/HACCP	Estimated Coef. After PR/HACCP
Large Firms	\$259,838.7	\$413,537.5
Small Firms	\$303,098	\$330,355.2
Very Small Firms	\$358,704	\$327,825.3

Source: Nganje, Mazzocco, and Mckeith (1999).

An equilibrium displacement model (EDM) was used to estimate costs of PR/HACCP implementation in the poultry industry. This model accounts for costs imposed by PR/HACCP, as well as substitution effects among poultry, pork, and beef products. In addition, these models allow for the approximation of losses or gains accruing to producers, consumers, or both when the market equilibrium is characterized by functions that are linear in supply and demand elasticities. The results indicate that the losses for the broiler industry range from \$4 million-\$63 million per year (Goodwin and Shiptsova, 2000).

Overall Assessment of PR/HACCP Implementation

The implementation of the PR/HACCP system by all meat and poultry firms is a very important step in improving food safety. PR/HACCP implementation makes firms accountable to society and government regulators in case of a major outbreak of foodborne illness. However, the controversy arising from the cost of PR/HACCP implementation versus its benefits requires further study in order to give firm managers and policy makers better understanding of the economic implications.

Previous research focused on the cost of PR/HACCP implementation versus its benefits using a Probit model (Muth et al., 2002) and a translog profit function (Nganje, Mazzocco, and Mckeith, 1999) to assess the economic impact on small and large meat and poultry firms. However, there has been no analysis done on predicting losses firms may incur after the implementation of PR/HACCP.

Value-at-Risk

Origin of VaR

In the past decade, the use of a risk analysis and management tools such as VaR by financial institutions has become extremely important due to market uncertainty about interest rates and prices. Volatility in exchange rates, interest rates, and commodity prices of the past few decades has provided the need for the use of VaR. Also, the proliferation of derivative instruments and the associate complexity of measuring risk have led to the demand for a portfolio-level quantitative measure of market risk (Linsmeier and Pearson, 2000).

The release of RiskMetrics by J.P. Morgan in 1994 provided the figure work to standardize the use of VaR throughout the industry. Corporate risk managers embrace VaR

as an important tool in the overall risk management process. In particular, upper level managers, who may or may not be well versed in statistical analysis, view VaR as an intuitive measure of risk since it concentrates only on adverse outcomes and is usually reported in dollars or returns. Not only financial institutions and investors embrace VaR, but so do regulators (Manfredo and Leuthold, 2001). The Basle Committee on Banking Supervision in 1996 permitted banks to calculate their capital requirements for market risk using their own proprietary VaR models. The greatest benefit of VaR may lie in the imposition of a structured methodology for thinking critically about risk (Linsmeier and Pearson, 2000). Financial institutions that go through the process of computing their VaRs, are forced to confront their exposure to financial risks and to set up a risk-management function to supervise the front and back offices. Thus, the process of getting to VaR may be as important as the number itself. Nevertheless, VaR is undoubtedly here to stay (Jorion, 1996).

What is VaR?

VaR gives a prediction with a certain level of confidence of potential portfolio losses that may be encountered over a specified time period due to adverse price movements in the portfolio's assets (Manfredo and Leuthold, 2001). VaR summarizes the worst expected loss over a target horizon within a given confidence interval (Jorion, 1996). For example, a VaR of 1 million dollars at the 95% level of confidence implies that overall portfolio losses should not exceed 1 million dollars more than 5% of the time over a given holding period. VaR measures the risk associated with a portfolio of assets and captures the extreme event that occurs in the lower tail of a portfolio's return distribution. It focuses on the downside risk (Manfredo and Leuthold, 2001). In light of the above definitions, it is

important to understand the various functions of VaR and its implication in the financial and non-financial institutions.

Advantages of VaR

VaR offers an attractive alternative to traditional risk measurement tools, such as the traditional mean-variance analysis,⁴ decision analysis,⁵ and real options.⁶ First, VaR gives managers the ability to think of risk in monetary terms instead of risk being classified with respect to standard deviation from the expected returns used in mean-variance and decision analyses. Although the real option methodology quantifies risk in monetary terms, it does not address the downside risk. VaR is easier to interpret and implement. The upper managers, who may or may not have a statistical background view, VaR as an easier tool to estimate or predict losses in dollar terms (Manfredo and Leuthold, 2001). Second, for a range of holding periods and probability levels, VaR estimates give a full description of the distribution of returns of a portfolio (Mahoney, 1995). Thus, VaR is a powerful lens through which to view the risk of a portfolio. Third, VaR focuses on downside risk. It tells the amount that firms or investors will lose in a particular given period. This is different from the traditional measures, which focus on the deviations from the expected returns as risk. Therefore, VaR is the most appropriate methodology for this study, to address risk in both monetary terms and downside risk

VaR estimates simplify the measurement of risk by combining the volatility estimate and the distributional assumption in a single step to arrive at a measure of

⁴ Mean-Variance analysis evaluates risky prospects based on the expected value and variance of possible outcomes.

⁵ Decision analysis is an explicit, quantitative approach for prescribing decisions under conditions of uncertainty.

⁶ Real Options is the application of derivations theory to the operation and valuation of real (physical) investment project.

potential downside risk (Mahoney, 1995). Finally, an advantage offered by VaR is the ability to capture the nonlinear payoffs of portfolios that contain options, or option-like instrument. One of the fundamental assumptions of most traditional risk measures, including analytical VaR, is that returns of a given amount above or below those expected occur with equal likelihood. This assumption can hold for portfolios that contain only physical assets, forward contracts, and futures contracts. The presence of options in a portfolio invalidates this assumption by introducing nonlinear payoffs. The ability to provide accurate estimates of risk exposure for portfolios that contain options, gives VaR a significant advantage over other measures (Hawes, 2003). Even though VaR has a number of advantages in its usage, there are some limitations to VaR. These limitations are clearly explained by Mahoney (1995).

Limitations of VaR

The two main limitations of VaR according to Mahoney (1995) are

1. VaR imposes the assumption that the portfolio does not change over the holding period. This assumption disallows certain dynamic trading strategies such as simple stop loss orders or more complex option replication strategies. However, VaR is intended to estimate losses due to significant market moves. During times of large market price movements, dynamic strategies are not likely to perform as predicted, due to higher search costs and higher trading costs (such as larger bid-ask spreads) during these stressful times. Therefore, the constant portfolio assumption is conservative, as it constrains the portfolio managers to a purely passive strategy.

However, it is a realistic description of the ability to trade during turbulent times, and

2. Another limitation of VaR is its lack of parsimony. Because there is no theoretical justification for any particular confidence level or holding period, many confidence level holding period pairs need to be calculated in order to arrive at a full understanding of the risks of a portfolio. This lack of parsimony must be weighed against the fact that the assumptions that lead to parsimony, such as normally distributed returns or serially uncorrelated time series, are not very accurate representations of financial data. Therefore, parsimonious representations of risk may be easier to communicate but lead to incorrect inferences if based on inaccurate simplifying assumptions. With the advantage and limitations of VaR, it is important to introduce the methodologies used to compute VaR and their limitations.

VaR Methodologies

This section introduces the three major methodologies used to compute or measure/estimate market risk using VaR. The three methodologies, namely parametric method also known as variance/covariance method, full-valuation and Monte Carlo simulation, are introduced without any mathematical derivation. The theory and mathematical derivation are reviewed in depth in Chapter 3. This section compares the three methodologies used to compute VaR.

Parametric or Variance/Covariance Method

The parametric model of VaR was motivated by the efforts of JP Morgan and the dissemination of its Risk Metrics methodology for developing estimates of standard

deviation and correlation among a portfolio of assets using an exponentially weighted average approach (Manfredo and Leuthold, 2001). The parametric method is based on the assumption that the underlying market factors have a multivariate normal distribution. Using this assumption, one can determine the distribution of market-to-market portfolio profits and losses, which is also assumed to be normal (Linsmeier and Pearson, 2000). Parametric methods of VaR provide a superior forecast of downside risk for portfolios with little options content (Jorion, 1997).

There are two main requirements to compute parametric methods. The first requirement is that, for each risk factor, forecasts of volatility and correlations are needed to help managers protect their firms against large losses. Second, positions on risk factors are needed to provide management with information necessary to implement other risk management tools to protect against future risk. However, parametric methods used to compute VaR have been criticized for two main reasons. The first main criticism of the parametric method is its assumption about normal distribution of return series. VaR literature has focused on the problem of non-normality often found in financial data and the potential bias that it causes when using parametric VaR models. However, because VaR attempts to explain information in the lower tail of a probability distribution, estimates of VaR can be distorted in the presence of leptokurtosis⁷ (Manfredo and Leuthold, 2001).

The second main criticism of the parametric method is its long-horizon forecast of VaR. Long-horizon forecasts of VaR, beyond a one day holding period, might fail to be accurate. The common practice for creating long-horizon VaR is to use one period ahead forecast and extend the forecast by multiplying the one period forecasts by the square root

⁷ Leptokurtosis is a condition of probability density curve having flatter tails and a higher peak at the mean than the normal distribution.

of the number of periods in the forecast horizon (Manfredo and Leuthold, 2001). However, scaling is misleading and tends to produce spurious magnification of volatility fluctuations with horizon (Christoffersen, Diebold, and Schuermann, 1998).

Full-Valuation Methods

Historical Simulation. Full-valuation methods attempt to model the entire return distribution instead of providing a point estimate of volatility (Manfredo and Leuthold, 2001). Full-valuation requires relatively few assumptions about the statistical distributions of the underlying market factors. Historical simulation is the simplest full-valuation procedure. It exposes the portfolio to past observation of the risky positions over a given historical period (Linsmeier and Pearson, 2000). The historical simulation method has been praised for its flexibility and ease of implementation. It does not rely on distributional assumptions, so deviations from normality are not a problem (Linsmeier and Pearson 2000; Mahoney, 1995). When option positions are in the portfolio, the historical simulation method captures the nonlinearity of the position. The historical simulation method is easy to understand, one of the prime considerations in using VaR estimates in business (Linsmeier and Pearson, 2000).

Despite the positive review about the historical simulation method, there are setbacks in its estimates. Long series of data are required and need continuous updating because more accurate distributions can be approximated only with large periods of data (Hendricks, 1996; Mahoney, 1995). Longer historical data sets present the possibility of including more extreme market moves associated with the tails of a probability distribution, potentially causing upward bias in the VaR estimate (Bulter and Schachter, 1997). In addition, quantiles estimated from full-valuation methods are more prone to estimation

error because they tend to have much larger standard errors than parametric methods. The latter use estimates of standard deviation (Jorion, 1996).

Monte Carlo Simulation. Monte Carlo simulation generates pseudo-random values of the risk factors of the portfolio based on a predetermined data generating process (Manfredo and Leuthold, 2001). Monte Carlo methods are the most flexible of VaR estimation techniques. The flexibility of Monte Carlo has its downside (Jorion, 1997); Linsmeier and Pearson, 2000). Monte Carlo methodology is criticized for estimating VaR because its process to specification process must be determined (Jorion, 1997). In addition, time variation can be added through Generalized Autoregressive Conditional Heteroscedasticity (GARCH) variance terms; however, this can be distorted with Monte Carlo methods, suggesting a trade-off between time variation and model flexibility (Jorion, 1997). Furthermore, Monte Carlo and full-valuation techniques do not have the ability to capture variance/covariance matrices to analyze the marginal contribution of an asset to overall portfolio risk (Ho, Chen, and Eng, 1996).

Comparison of VaR Methods

The similarities between the parametric and full-valuation methods include

1. Both the full-valuation and parametric methods provide estimates of the total variances of a distribution and they do not explicitly model the distribution tail,
2. These methods are sensitive to data sets used in developing and predetermined confidence level, and
3. Also, both full-valuation and parametric methods rely on the use of historical data.

The differences between the parametric and full-valuation methods include

1. The parametric method is less sensitive to estimation error and it is easier to implement than the full-valuation method,
2. The parametric method assumes all assets to be normally distributed; full-valuation method focuses on the entire returns,
3. The full-valuation method is flexible but it is sometimes criticized for not being able to capture time varying volatility often found in financial returns, where as the parametric method is able to capture time varying volatility through the incorporation of conditions of volatility forecasts,
4. The parametric method works well with the limited options content and full-valuation method captures the risk option like instruments in a portfolio, and
5. The parametric method is usually more difficult than full-valuation method to explain to firm managers or individuals that do not have the knowledge of financial operations.

Applications of VaR in Agricultural Economics

The use of VaR as a risk reporting and measurement tool has several potential applications in agriculture. Publicly traded agribusiness firms must comply with SEC regulations concerning the reporting of positions in highly market sensitive assets, including spot commodity, futures, and options positions (Manfredo and Leuthold, 2001). The use of VaR in agriculture can help firm managers to employ a specific management strategy or strategies to reduce their exposure to risk.

Although the study and application of VaR has received considerable attention in the financial literature, its implementation in the agricultural economics literature is limited

(Hawes, 2003). The best-known work done with VaR in agricultural economics is that of Manfredo and Leuthold (2001). In this study, a portfolio of risk assets, which included fed cattle prices, feeder cattle prices, and corn prices, was built. The cattle feeding margin was defined as fed cattle prices * weight - feeder cattle prices * weight - corn prices * amount fed. The main objective of this study was to examine VaR measures in the context of cattle feeding margin. Full-valuation and parametric methods were used to predict large losses in the cattle-feeding margin with a particular level of confidence and time horizon.

This study used VaR to predict losses for a characteristic and small turkey processing plant. The data required for this study include monthly wholesale price of turkey (\$/lb), wholesale cost of turkey (\$/lb), monthly food recalls and number of turkeys processed. Secondary data was obtained to compute the VaR prior to and after PR/HACCP implementation. The years prior to and after PR/HACCP implementation are 1995-2000 and 2001-2003, respectively. In addition, primary data was used to compute VaR for a small turkey processing plant using microbial count to determine the actual risk reduction benefits of PR/HACCP system. The focus of this study is to examine whether PR/HACCP implementation significantly reduces food safety risks and improves the profit situation of the turkey processing plant.

CHAPTER 3. THEORETICAL CONSTRUCTS OF VALUE-AT-RISK

The concept of VaR can be traced to the late 1920s to capital requirements the New York Stock Exchange imposed on member firms (Holton, 1998). VaR also has roots in portfolio theory, and a crude VaR measure was published in 1945.

Markowitz and Roy in 1952 used VaR measures that considered covariance among risk factors to reflect hedging and diversification effects. They were working to develop a means of selecting portfolios that would, in some sense, optimize reward for a given level of risk (Holton, 1998). Markowitz (1952) used a variance of simple return metric. Roy (1952) used a metric of shortfall risk that represented an upper bound on the probability of the portfolio's gross return being less than some specified "catastrophic return."

Baumol first proposed the concept of VaR when examining a model referred to as the Expected Gain-Confidence Limit Criterion in 1963 (Alexander and Baptista, 2000). Baumol found situations where some unacceptable portfolios can actually be found among the set of portfolios that Markowitz's selection criterion lists as efficient (Hawes, 2003). In this case, the confidence level selection criterion is used to incorporate both the risk and the expected return into one criterion that captures the relationship between them. Baumol (1963) used the equation $L = E - K\sigma$ to represent the lower confidence limit, where E represents the expected portfolio return, σ is the standard deviation of the portfolio returns, and K is the number of standard deviations from the expected return corresponding to the desired level of confidence.

This chapter focuses on the theoretical constructs of VaR and its alternative methodologies. First, brief descriptions about the quantitative factors affecting the measures of VaR are introduced. Second, variables and the equation used to compute VaR

of a portfolio are explained. Third, the description and mathematical derivations are presented. Fourth, the comparisons of three VaR methodologies are explained in detail, taking into account six main characteristics: Accuracy, Ease of Explanation to Management, Ease of Implementation, Reliability of Results, Flexibility, and Cost Effectiveness. Fifth, Model Validation is described and the Backtesting methods are presented. Finally, the explanation about Stress Testing and comparison between VaR and portfolio theory are presented.

Selection of Quantitative Factors

Time horizon and confidence interval selection are very important in the measures of VaR. The key in choosing both relates to the specific application for which the VaR statistic will be used (Jorion, 2001). This section focuses on their impact, and how they could affect the interpretation of VaR results.

Time Horizon

The choice of time horizon when using VaR as a risk-reporting tool is determined by the scope of management decision from firm to firm. The time horizon can range from 1 day, 1 week, 1 month, or 1 year, depending on the portfolio composition. The parameter time is determined by the entity's horizon. Those who actively trade their portfolios, such as financial firms, typically use 1 day; while institutional investors and non-financial corporations may use longer holding periods. For this study, monthly VaR are used because the PR/HACCP team for this small turkey processing plant meet on monthly basis to evaluate the PR/HACCP system. A VaR number applies to the current portfolio, so an assumption underlying the computation is that the current portfolio will remain unchanged throughout the holding period. This may not be reasonable, particularly for long holding

periods (Linsmeier and Pearson, 2000). The shortcomings of short and long horizon selection can result in users of VaR choosing a relatively short horizon and scale the statistic up to longer horizons by multiplying by the square root of time (Jorion, 2001). However, scaling is accurate only when returns are independently and identically distributed. Also, modeling volatility only at one short horizon, followed by scaling to convert to longer horizons, is likely to be inappropriate and misleading because temporal aggregation should reduce volatility fluctuations, whereas scaling amplifies them. The use of scaling in the application of VaR can be useful; however, it can sometimes result in inaccurate results (Diebold et al., 1998).

Overall, the selection of time horizon differs from firm to firm. It is important to note that time horizon should reflect the portfolio composition and its specific application using VaR as a tool to measure risk. Consistency is a very important factor in the application of VaR.

Confidence Interval

The choice of confidence interval in the application of VaR is similar to the choice of time horizon as a benchmark. Consistency is very important since it is used to compare results in different scenarios and time over different periods.

Confidence interval, in the measure of potential loss application of VaR, is insignificant as long as decision makers realize that VaR is a probabilistic measure and that losses exceeding the VaR figures should be expected (Hawes, 2003). However, it is important to note that the VaR results are not the absolute worst loss a firm can expect because firms could sometimes experience losses greater than those predicted.

In order to determine the confidence interval, there are two aspects that need to be considered. The first aspect deals with the risk aversion of the firm. The second aspect deals with costs associated with a loss exceeding the VaR. If the cost of exceeding the figure merely results in borrowing, confidence intervals can be set relatively low. However, if losses are greater than the VaR, firms need to set a high confidence interval (Jorion, 2001).

To interpret VaR numbers, it is crucial to keep in mind the confidence interval and time horizon. Without them, VaR numbers are meaningless. For example, two companies holding identical portfolios will come up with different VaR estimates if they make different choices of confidence interval and time horizon. Obviously, the loss that is suffered with a probability of only 1% is larger than the loss that is suffered with a probability of 5%. In addition, the choice of time horizon and confidence interval can have an impact on out-of-sample test (which will be explained later in this chapter) (Linsmeier and Pearson, 2000).

Construction of Value-at-Risk

VaR gives a prediction with a certain level of confidence (1-c) of potential portfolio losses that may be encountered over a specified time period (t) due to adverse price movements in the portfolio's assets (Manfredo and Leuthold, 2001). In order to compute the VaR of portfolios, the initial investment and rate of return must be defined. Second, the portfolio value at the end of target horizon is defined. Third, the mean and standard deviation of the rate of return are defined, as well as the change in the time interval. Fourth, the VaR, as dollar loss relative to what was expected is expressed.

The initial investment and rate of return on the portfolio of assets are defined as W_0 and R , respectively. The end of target horizon is defined as the $W = W_0 (1+R)$. The annual mean and standard deviation of R are μ and σ , respectively. The change in time interval is represented by Δt . If the returns of the portfolio are uncorrelated, then the expected return and risk are defined over the holding time as $\mu \Delta t$ and $\sigma \sqrt{\Delta t}$, respectively (Jorion, 1996).

The VaR as a dollar loss relative to what was expected is defined by Jorion (1996) as

$$\begin{aligned} \text{VaR} &= E(W) - W^* \\ &= W_0(\mu - R^*). \end{aligned} \tag{1}$$

Equation 1, W^* represents the lowest portfolio value at a particular level of confidence. Also, R^* is the cutoff return of a portfolio of assets which is also equivalent to finding the VaR of a portfolio of assets.

The above description of variables and equations related to VaR computation are important to understand in order for managers and policy makers to implement or take steps and decisions that would reduce their exposure to financial risk. In the next section, the two main measures of VaR, namely full-valuation and parametric methods, and their characteristics, are discussed in detail. In the presentation, a VaR graph is used to illustrate the downside risk that is expressed by both the full-valuation and parametric methods.

Value-at-Risk Characteristics and Computations

Full-Valuation Method and Its Characteristics

This section provides a brief explanation about full-valuation method and its significant assumptions about the distribution of returns. Also, a complete demonstration of the entire distribution of returns is expressed. Finally, a brief summary and limitations of full-valuation methods are mentioned.

The full-valuation method attempts to model the entire return distribution instead of providing a point estimate of volatility (Manfredo and Leuthold, 2001). Full-valuation requires relatively few assumptions about the statistical distributions of the underlying market factors. There are two procedures in computing the full-valuation method. These procedures are historical and Monte Carlo simulations.

Historical simulation is the simplest full-valuation procedure. It exposes the portfolio to past observation of the risky positions over a given historical period (Linsmeier and Pearson, 2000). The historical simulation method has been praised for its flexibility and ease of implementation. It does not rely on distributional assumptions, so deviations from normality are not a problem (Linsmeier and Pearson, 2000; Mahoney, 1995). When option positions are in the portfolio, the historical simulation method captures the nonlinearity of the position. The historical simulation method is easily understood by management, one of the prime considerations in using VaR estimates (Linsmeier and Pearson, 2000). Despite the positive review about historical simulation method, there are setbacks in its estimates.

Long series of data are required and need continuous updating because more accurate distributions can be approximated only with large periods of data (Hendricks,

1996; Mahoney, 1995). Longer historical data sets present the possibility of including more extreme market moves associated with the tails of a probability distribution, potentially causing upward bias in the VaR estimate (Bulter and Schachter, 1997). In addition, quantiles estimated from full-valuation methods are more prone to estimation error because they tend to have much larger standard error than parametric methods which use estimates of standard deviation (Jorion, 1996).

The Monte Carlo simulation generates pseudo-random VaR factors of the portfolio based on a predetermined data generating process (Manfredo and Leuthold, 2001). Also, Monte Carlo methods are the most flexible of VaR estimation technique. However, Monte Carlo methodology is criticized for estimating VaR because it is prone to specification process (Jorion, 1997). In addition, time variation can be added through GARCH variance terms; however, this can be distorted with Monte Carlo methods, suggesting a trade-off between time variation and model flexibility (Jorion, 1997). Furthermore, Monte Carlo and full-valuation techniques do not have the ability to capture variance/covariance matrices to analyze the marginal contribution of an asset to overall portfolio risk (Ho, Chen, and Eng, 1996).

The advantages and disadvantages of full-valuation procedures are very important for the construction of full-valuation procedure of VaR. The next section presents in detail derivation of the full-valuation procedure (Jorion, 1996).

General Distribution

VaR can be derived from the probability distribution for the future portfolio value where (Jorion, 1996)

$$c = \int_{W^*}^{\infty} f(w)dw, \quad (2)$$

or the probability of a lower value than W^* can be expressed as $1-c$,

$$1-c = \int_{-\infty}^{W^*} f(w)dw. \quad (3)$$

Future portfolio value is defined as $f(w)$ and c is defined as the confidence level at a given time. Equation 3 also explained that the area from $-\infty$ to W^* should sum up to $1-c$. The expression $1-c$ is the probability that the firm would lose a particular amount in a given holding period. The above distribution can be valid for a discrete or continuous, fat or thin tailed distribution.

Parametric Method and its Characteristics

Parametric models of VaR have been motivated by the efforts of JP Morgan and the dissemination of its Risk Metrics methodology for developing estimates of standard deviation and correlation among a portfolio of assets using an exponentially weighted average approach (Manfredo and Leuthold, 2001). Also, the parametric method is based on the assumption that the underlying market factors have a multivariate normal distribution. Using this assumption, one can determine the distribution of market-to-market portfolio profits and losses, which is also assumed to be normal (Linsmeier and Pearson, 2000). In addition, parametric methods of VaR provide a better forecast of downside risk for portfolios with little options content (Jorion, 1997).

In order to compute parametric methods, there are two main requirements. The first requirement is that each risk factor, forecasts of volatility, and correlations are needed to help managers protect their firm against large losses. Second, positions on risk factors are needed to provide management with information necessary to implement other risk management tools to protect against future risk. However, parametric methods used to compute the VaR have been criticized for two main reasons.

The first criticism of the parametric procedure lies in the assumption of normality of returns. For example, the VaR literature has focused on the problem of non-normality often found in financial data, and the potential bias that it causes when using parametric VaR models. Because VaR attempts to explain information in the lower tail of a probability distribution, estimates of VaR can be distorted in the presence of leptokurtosis. The second major criticism of the parametric procedure lies in its long horizon forecast of VaR. Beyond a one day holding period, VaR of a long horizon forecast of VaR might be inaccurate (Manfredo and Leuthold, 2001).

Normal Distributions

The general distribution, $f(w)$, is converted into standard normal distribution $\Phi(\varepsilon)$, where ε is a random variable with a mean of 0 and a standard deviation of 1. R^* associated with the standard normal distribution is expressed as (Jorion, 1996)

$$-\alpha = \frac{\mu\Delta t - R^*}{\sigma\sqrt{\Delta t}}, \quad (4)$$

where R^* is considered the cutoff return of the portfolio of assets.

VaR of a portfolio can be found in terms of W^* , R^* , or α which are portfolio value, cutoff return and normal deviation, respectively (Jorion, 1996). The following equations illustrate the above concept:

$$\begin{aligned}
1-c &= \int_{-\infty}^{w^*} f(w)dw, \\
&= \int_{-\infty}^{R^*} f(r)dr, \\
&= \int_{-\infty}^{-\alpha} \Phi(\varepsilon)d\varepsilon.
\end{aligned} \tag{5}$$

The VaR can be expressed as

$$VaR = W_0 \alpha \sigma, \tag{6}$$

where W_0 is the initial portfolio value, α is the normal deviate associated with $1-c$ and σ is the portfolio standard deviation. The critical element of parametric VaR is the estimate of portfolio standard deviation (σ), also referred to as portfolio volatility (Manfredo and Leuthold, 2001). The portfolio variance is defined in equation 7

as

$$\begin{aligned}
\sigma_i^2 &= p_{wpt}^2 \sigma_{wpt}^2 + p_{wct}^2 \sigma_{wct}^2 + p_{HB}^2 \sigma_{HB}^2 + 2 p_{wpt} p_{wct} \rho_{wpt,wct} \sigma_{wpt} \sigma_{wct} + 2 p_{wpt} p_{HB} \rho_{wpt,HB} \sigma_{wpt} \sigma_{HB} \\
&+ 2 p_{wct} p_{HB} \rho_{wct,HB} \sigma_{wct} \sigma_{HB}.
\end{aligned} \tag{7}$$

In equation 7, i represent the wholesale price of turkey (wpt), wholesale cost of turkey (wct), and the net economic benefit of PR/HACCP (HB) of portfolio variance.

σ_{wpt}^2 , σ_{wct}^2 , and σ_{HB}^2 are the variances of wholesale of turkey, wholesale cost of turkey, and net economic benefit prior to and after PR/HACCP implementation. The portfolio weights

are represented as p_{wpt} , p_{wct} , and p_{HB} . Finally, ρ_{wpt} , ρ_{wct} , and ρ_{HB} are the correlation coefficients between the return.

Comparison of Value-at-Risk Methodologies

In Chapter 2, a brief description of the three VaR methodologies, parametric method, historical simulation, and Monte Carlo simulation, was introduced. In this chapter, a more detailed examination of the three VaR methodologies is presented. This section considers five different characteristics of the three VaR methodologies: Accuracy, Ease of Explanation to Management, Ease of Implementation, Reliability of Results, Flexibility, and Cost Effectiveness.

Accuracy

The parametric method is sometimes criticized because of its inability to capture nonlinear instruments. An example of nonlinear instruments is options. Linsmeier and Pearson (2000) stated that the limitation of the parametric method to capture nonlinear instruments like options and replace them with “delta-equivalent” spot positions can inadequately capture the values of the option with changes in the underlying rates and prices. However, the parametric method is less severe if the options or option-like instruments have a holding period of one day. In a longer holding period, like a month or two months, changes can occur in the rates or prices, and VaR estimates produced cannot rely on a position with significant option content (Linsmeier and Pearson, 2000). On the other hand, the historical and Monte Carlo methods worked, regardless of the presence of options or options-like instruments.

The simulation method works well, regardless of the presence of options in the portfolio, because they recomputed the value of the portfolio for each draw of the basic

market factors. In doing this, they estimate the correct distribution of portfolio value. The distribution of the portfolio value generated by Monte Carlo simulation depends upon the assumed statistical distribution of the basic market factors and the estimates of its parameters, both of which can be wrong and therefore lead to errors in the calculated VaR. Similarly, the distribution of the portfolio value generated by historical simulation will be misleading if the prior N (number of weeks or months) days from which the historical sample was drawn were not representative (Linsmeier and Pearson, 2000).

Ease of Explanation to Management

The parametric method is usually more difficult than the full-valuation method to explain to firm managers or individuals that do not have the knowledge of financial operations. The conceptual simplicity of historical simulation makes it easiest to explain to senior managers. However, the parametric method is difficult to explain to those who lack technical training because the key step, the mathematics of the normal distribution in calculating portfolio standard deviation and VaR, is simply a black box. Monte Carlo is more complex to explain. Choosing the statistical distribution to represent changes in the market factors and engaging in the pseudo-random sampling from that distribution are simply alien to most people (Linsmeier and Pearson, 2000).

Ease of Implementation

The historical simulation method is easy to implement for a portfolio with past historical values on the market factors. However, it is sometimes difficult to get historical values of past market factors required for a given holding period. Manfredo and Leuthold (2001) stated that, historical simulation method is easy to implement and does not rely on the assumption of normal distribution. However, Linsmeier and Pearson (2000) noted that,

although historical simulation is easy to implement, the challenge is that the risk manager should have the time series data for each asset over the last N (number of weeks or months) periods. In addition, Jorion (2001) explained that, when the historical data of market factors are available for a relatively small holding period the computation is faster. However, large and complex portfolios lead to cumbersome implementation and can reduce the accuracy of the VaR estimation.

The parametric method is easy to implement when a software package is available. Hawes (2003) stated that, when the software is not available and the extensive variance/covariance matrix must be constructed manually, the methodology becomes more involved. Also, Linsmeier and Pearson (2000) noted that, variance/covariance method can be moderately difficult to implement for portfolios which include currencies and other types of instruments not covered by the available systems.

Monte Carlo simulation is difficult to implement without a software package. This approach can become as complex as the variance/covariance approach. Also, it is difficult to select the distribution of returns or estimate the parameter of the distribution. Linsmeier and Pearson (2000) explained that, carrying out the simulation is not difficult because the pseudo-random number generators are available as spreadsheet add-ins. However, selecting the distribution and selecting or estimating the parameters requires a high degree of expertise and judgment. Another disadvantage of Monte Carlo simulation is that, for large portfolios, the computations can be time consuming.

Reliability of Results

All three VaR methodologies rely on historical data to compute VaR for a portfolio of assets. The use of historical data can sometimes overstate or understate the risk of the

portfolio if there are dramatic movements in the prices. However, one way of confirming the reliability of results is through model validation with test statistics. This is done by comparing the actual changes in value to the VaR amounts. Linsmeier and Pearson (2000) stated that, model validation is feasible because the VaR approach explicitly specifies the probability with which actual losses will exceed the VaR amount. In doing this, one can compare the different VaR estimates and choose the VaR with the less violation or the smallest summary statistics.

Flexibility

Some managers believe that historical prices can not accurately predict/estimate future returns, or that the future prices are overestimated or underestimated.

Overestimation or underestimation of future prices can occur due to political, structural, or economic changes. These types of changes can be analyzed using “what-if” analysis.

Linsmeier and Pearson (2000) explained that, historical simulation is directly tied to historical changes, and therefore it can use “what-if” analysis. In contrast, it is very easy to carry out this sort of “what-if” analysis in the variance/covariance and Monte Carlo simulation methods. Variance/covariance and Monte Carlo methods use historical data to estimate the parameters of the statistical distribution of the changes in the market factors. However, the historical estimates can be overridden and any consistent parameters can be used.

Cost Effectiveness

The cost of implementing the three VaR methodologies varies from firm to firm. In order to implement one of the VaR methodologies, the firm would have to examine the situation at hand. If the data required for implementing for example a historical simulation

is not available, it can sometimes be very costly to collect from academic institutions or governmental or nongovernmental organizations. Also, the availability of shelf software is very important because the parametric and Monte Carlo methods rely heavily on it. If the shelf software is not available, it can be time consuming to compute parametric and Monte Carlo simulation models. Of the three VaR methodologies, the Monte Carlo simulation method is considered the most expensive. Jorion (2001) stated that, time consuming simulations make significant hardware demands, and the extensive intellectual power necessary to develop a Monte Carlo simulation model can be very costly.

Model Validation

VaR models are developed to predict or estimate the risk associated with a particular portfolio of assets. However, in order to produce good results, one has to test whether the model was accurate in predicting the risk associated with that portfolio of assets. This concept is referred to as model validation. There are several tests that can be used to determine accuracy; however, this study focuses on backtesting.

Jorion (2001) defined backtesting as a statistical method used to verify that actual losses are consistent with losses predicted by a VaR model. Also, backtesting is used by regulators in order to verify the accuracy of the firms' VaR. Hawes (2003) noted that, regulators use VaR statistics in assessing the risk exposure of a firm, which can affect capital reserve requirements and insurance premiums. In this case, firms are very careful in selecting VaR models because they do not want to overestimate or underestimate the risk associated with their portfolio of assets.

Backtesting is not absolute. Cassidy and Gizycki (1997) stated that, the main challenge with backtesting is that the portfolio for which the VaR statistics is computed can

differ from the actual returns. This is the case because VaR assumes that portfolio is constant over a time horizon, which is unrealistic. It is also important to note that backtesting is done for actual and hypothetical returns.

Backtesting

The development of backtesting followed the procedures of (Manfredo and Leuthold, 2001; Lopez, 1997). The probability that the X violations of VaR for a sample of N is represented as

$$\Pr (X; \delta, N) = \binom{N}{X} \delta^X (1 - \delta)^{N-X}, \quad (8)$$

and the likelihood ratio test statistic is (Lopez, 1997)

$$\text{LR} (\delta) = 2 [\ln (\delta^{*X} (1 - \delta^*)^{N-X}) - \ln (\delta^X (1 - \delta)^{N-X})], \quad (9)$$

with asymptotic χ^2 distribution and 1 degree of freedom.

Equation 9, the null hypothesis is $\delta = \delta^*$ in which δ is the desired coverage level (5%) corresponding to the 95% level of confidence. δ^* is defined as X/N, where X is the number of realized violations and N is the number of out-of-sample observations.

Another test of bias in VaR estimation was conducted using Mahoney (1995) procedures of binomial probability distribution. The Z test is used as bias test where large samples are normal distributed such that

$$Z_c = L_{\text{realized}} - N(1 - c) / \sqrt{Nc(1 - c)}, \quad (10)$$

L_{realized} is the number of observed violations of VaR at a given confidence level c (Mahoney, 1996). $N(1 - c)$ represents the number of violation of VaR estimations. N is the number of out-of-sample observations and c is the confidence level represented in decimal form. The variance of the VaR estimate is expressed as $Nc(1 - c)$. When the Z test is positive or

negative, VaR underestimates or overestimates the actual downside risks. If there are several VaR measures which are “well calibrated,” the model with the smallest test statistics will be preferred.

Stress Testing

VaR is a single, summary statistical measure of possible portfolio losses. Specifically, VaR is a measure of losses due to “normal” market movements (Linsmeier and Pearson, 2000). However, the estimate of VaR does describe the magnitude of losses in abnormal market conditions which can have significant profits or losses effect. Jorion (2001) stated that, VaR estimation approaches rely on historical data and the data does not account for abnormal market conditions.

Teker and Akcay (2003) explained that, stress testing is a technique to measure the strength of the model under sharp variations in prices and correlations among asset returns. Also, stress testing can be applied to scenarios of past crises in order to capture the behavior of risk factor changes in the periods of the crisis. However, the stress scenario may be sensitive to specific portfolio risks.

Stress testing is very important in the estimation of VaR models because it can inform both regulators and decision makers about the worst abnormal losses for different case scenarios. Hawes (2003) explained that, stress testing is used to supplement VaR and allows the risk manager to evaluate unlikely scenarios and the effects of these potential events on returns.

Summary

This chapter began with a brief introduction of VaR and its contribution to financial institutions. The selection of the two quantitative factors, time horizon, and confidence

level, were discussed. There was discussion about variables and equations used to compute VaR. Next, the characteristics and computation procedures for both general and normal distributions were derived. The next section focused on three main VaR methodologies: parametric, historical simulation, and Monte Carlo simulation, and their characteristics, advantages, and disadvantages.

Model validation was defined and the use of backtesting procedures was explained in detail. In addition, stress testing was defined and its supplement to VaR statistics was discussed. In the next chapter, the VaR procedure used in this thesis is discussed. Also, a detailed description of the case study, data source, and empirical models are presented.

CHAPTER 4. EMPIRICAL METHODS AND PROCEDURES

This chapter introduces, in detail, the three alternative scenarios used to analyze VaR, incorporating the impact of PR/HACCP on food recalls and microbial outbreak. The three alternative scenarios described are

1. Prior to PR/HACCP implementation,
2. After PR/HACCP implementation, and
3. Under more stringent risk management strategies.

The empirical models and procedures used are also described in detail. Finally, the data for each variable in the empirical models, and their sources, are presented.

Scenario Studies

The three alternative scenarios are developed to evaluate the effectiveness of VaR methodology in predicting food safety losses attributable to food recalls, and microbial outbreak incurred by a characteristic and small turkey processing plant. Scenario 1 focuses on the impact of food recalls prior to PR/HACCP, where VaR is used to evaluate the losses incurred by a characteristic turkey processing plant. Scenario 2 focuses on the period after PR/HACCP implementation by a characteristic turkey processing plant and the impact of the PR/HACCP system on food recall and the plant performance. Also, VaR is used to evaluate the losses incurred during this period by a characteristic turkey processing plant. Finally, scenario 3 evaluates the impact of more stringent risk management strategies under PR/HACCP implementation, where VaR is used to predict the losses incurred by a small turkey processing plant.

Scenario 1: Prior to PR/HACCP Implementation

In scenario 1, the period ranging from 1995-1999 represented prior to PR/HACCP implementation. During this period, a characteristic turkey processing plant was not required to implement PR/HACCP. PR/HACCP implementation became mandatory for characteristic turkey processing plants in 2000. This section examined the impact of food recall and profitability of characteristic turkey processing plants during non-mandatory PR/HACCP implementation using historical VaR methodology.

Scenario 2: After PR/HACCP Implementation

The period of after PR/HACCP implementation ranged from 2000-2003 for a characteristic turkey processing plant. This section examined the relationship between PR/HACCP implementation and its impact on food recall and profitability of a characteristic turkey processing plant using historical VaR methodology.

Motivation for Scenario 3: Under More Stringent Risk Management Strategies

Scenario 1 examined the impact of food recalls on characteristic turkey processing plants' profitability during non-mandatory PR/HACCP implementation from 1995-1999 using historic data and VaR methodology. Scenario 2 examined the impact of implementing PR/HACCP and its impact on food recall and profitability of characteristic turkey processing plants' also using historic recall data and VaR methodology. However, these analyses did not take into account structure changes like vertical integration, production contracts, and consolidation that may have occurred in the turkey industry during 1995-2003 impacting number of food recall and plants' performance.

According to Martinez (2002), prior to PR/HACCP implementation, production contracts and vertical integration accounted for 52% and 28%, respectively, in the turkey

industry. After PR/HACCP implementation, production contracts and vertical integration increased to 56% and 32%, respectively. Also, Ollinger, MacDonald and Madison (2000) noted that, the production for turkey was seasonality during the past three decades; however, the increase in the demand for turkey shifted the production of turkey from seasonality production to year round production. This shift in demand and increase in production of turkey led to consolidation in order to exploit economies of scale. Also, if the growth in demand for turkey diminished, there is likely to be more consolidation as small plants are unable to cover the cost of production. Furthermore, Bank of America (1999) stated that, consolidations are intended to increase and stabilize margins with acquisitions of value-added products. However, it is difficult to quantify how industry changes affected food recalls or improved characteristic turkey processing plants' profitability. Therefore, scenario 3 examined the actual risk reduction benefit of PR/HACCP implementation by a small turkey processing firm, using actual microbial count data collected in an experiment to examine the effectiveness of generic⁸ and augmented⁹ PR/HACCP systems.

Background of the Small Turkey Processing Plant

The small turkey processing plant has been in operation since 1930s. Initially, the plant produced a holiday food commodity, the whole bird, which consisted of seasonal operation and seasonal workers. However, the plant extended and underwent name and ownership changes. The plant enjoyed an economic boom and seasonal production of whole turkeys, which was replaced by a year round production of turkey part and full bird.

⁸ Generic PR/HACCP is the mandate CCPs by FSIS regulation. In this study, the generic PR/HACCP comprised of Pre-wash (CCP5) and Visual Inspection (CCP7).

⁹ Augmented PR/HACCP is the addition CCPs implemented by turkey processing plants to further reduce the risk of contamination along the line of production; but, they are not mandated by FSIS regulation.

This plant has approximately 300 employees in different categories which include management, supervisors, line worker, janitorial, and support service. In the mid-1990s, the plant decided to implement the PR/HACCP system in order to prevent potential hazards along the line of production and ensure consumer safety. Finally, the USDA praised this plant for consistently meeting and surpassing quality and safety standards compared to other turkey processing plants. This plant is considered representative of all the industry operational aspects.

Model Selection and Empirical Methods

The first important step is to select the appropriate VaR methodology. Parametric, historical simulation and Monte Carlo simulation were various VaR methodologies considered for this study. Historical simulation was selected. The historical simulation method has been praised for its flexibility and ease of implementation. Also, it does not rely on distributional assumptions, so deviations from normality are not a problem (Linsmeier and Pearson 2000; Mahoney, 1995).

The second step is to determine the confidence interval and time horizon that is suited for the situation and goal of this study. For this study, 95% and 99% confidence intervals were selected to compare the robustness of the model when out-of-sample testing was conducted. Also, the time horizon chosen for this study was based on monthly data collected for characteristic and small turkey-processing plants. The monthly data collected for volume of food recalls, prices of wholesale turkey, and cost of wholesale turkey made it easy to compute monthly VaR for the small and characteristic turkey processing plants. For example, monthly VaR with confidence interval of 95% indicates the amount that

characteristic and small turkey processing plants will not lose more than 5% of the time in a given month.

Analytical Procedures

In order to estimate the statistical distribution of the data used in the model, BestFit™ technique was employed. BestFit™ is a component of the @Risk™ software package provided by Palisade Corporation (2001). It is used to provide an accurate approximation of each observed data set. All of the data sets used in this analysis were continuous data. BestFit™ was used to estimate all of possible distributions for each data set.

After the parameters are estimated, BestFit™ ranks the distributions of the continuous data sets. The ranking differs depending on the fit statistic in use. The three fit statistics in used are chi-squared,¹⁰ Kolmogorov-Smirnov,¹¹ and Anderson-Darling.¹² The fit statistic with the lowest number is selected as the best fit distribution. However, the choice of best fit distribution should also be based on the underlying assumptions about the model and how it may impact the end results.

¹⁰ Chi-Squared test compares the number of sample observations found in discrete classes to that predicted by the proposed model. Chi-squared test is best suited for discrete random variables and discrete classes (Hollander and Wolfe, 1973).

¹¹ Kolmogorov-Smirnov test provides a simpler procedure for comparison, although corrections to the standard test statistic are required when the parameters of the proposed distribution are estimated from the sample, and these corrections are difficult to determine (Crutcher, 1975).

¹² Anderson-Darling test involve graphical transformations of the CDF such that a given distribution plots as a straight line (Benjamin and Cornell, 1970).

Scenario 1: Empirical Model and Procedures

In this section, the procedures used to compute VaR from 1995-1999 followed procedures used by Manfredo and Leuthold (2001). The observed turkey processing margin is defined as

$$OM_{t(\$ / lb)} = WPT_t - WCT_t, \quad (11)$$

where

$OM_{t(\$ / lb)}$ = Observed Margin in current period,

WPT_t = Wholesale price of turkey in current period, and

WCT_t = Wholesale cost of turkey in current period.

Next, the natural log of the prices and costs of turkey were computed for the previous 60 months in order to calculate the historical rate of returns of turkey.

The historical returns of turkey are defined by Manfredo and Leuthold (2001) as

$$R_t = \ln(P_t) - \ln(P_{t-1}), \quad (12)$$

where

R_t = Monthly return of turkey,

\ln = Natural logarithm,

P_t = Current price of turkey, and

P_{t-1} = Previous price of turkey.

The hypothetical future values (forecasted prices) and cost of turkey were computed as:

$$P_t^* = P_t (1 + R_{t-T}) \quad (13)$$

$$C_t^* = C_t (1 + R_{t-T}) \quad (14)$$

respectively for all $T = 1 \dots 60$ or $T = 61 \dots 108$.

Then, the hypothetical margin was defined as

$$HM_{t-1} = P_{t-1}^* - C_{t-1}^*, \quad (15)$$

where

HM_{t-1} = Hypothetical margin previous period,

P_{t-1}^* = Hypothetical price of turkey previous period, and

C_{t-1}^* = Hypothetical cost of turkey previous period.

In the next step, the hypothetical margin was subtracted from the observed margin, and BestFitTM distribution technique was employed to determine the statistical distribution that best fit the data. Finally, the selected distribution was simulated 1,000 times and the VaR at 95% level of confidence was estimated.

Scenario 2: Empirical Model and Procedures

In scenario 2, the observed turkey processing margin was comprised of the wholesale price of turkey, wholesale cost of turkey, and the net economic benefit of PR/HACCP system. The net economic benefit of PR/HACCP system comprised of risk reduction benefit of PR/HACCP less the cost of PR/HACCP implementation. The same procedures used in scenario 1 to compute observed margin, historical returns, hypothetical margin, and the difference between hypothetical margin and observed margin were employed in scenario 2. However, one of the major differences between scenario 1 and scenario 2 was the inclusion of net economic benefit of PR/HACCP and the time period from 2000-2003.

To compute the net economic benefit of PR/HACCP, risk reduction benefit of PR/HACCP system was computed using class of recall and the year of PR/HACCP implementation to conduct multinomial-logit regression analysis. The class of recall was used as a dependent variable and year prior to and after PR/HACCP implementation period as an independent variable in order to obtain the elasticity of probabilities for Class 1 and 2 recalls. Class 3 recall was omitted from the study because there was only 1 type 3 recall from 1995-2003.

Reasons for Using Multinomial Logit Model

A multinomial logit model was used in this study because the dependent variable was qualitative in nature and its classification has more than two categories. Also, the marginal impacts and elasticities of PR/HACCP on the two recall categories can be estimated. Kennedy (1996) stated that, categorical variables that can be classified into many categories are called polychotomous variables. The estimation is undertaken by means of a generalization of probit¹³ or logit¹⁴ models, the multinomial probit and multinomial logit models, respectively. These generalizations are motivated by employing the random utility model.¹⁵

The three major advantages of multinomial logit model are

1. The advantage of this model is its computational ease,

¹³ Probit Model is a nonlinear model that relates the choice probability P_i to explanatory factors in such a way that the probability remains in the (0, 1) interval.

¹⁴ Logit Model is an alternative to the probit model in that it is linear and uses the probability density function as oppose to cumulative distribution function as a choice of probabilities.

¹⁵ Random utility model is a utility to a consumer of an alternative which is specified as a linear function of the characteristics of the consumer and the attributes of the alternatives, plus an error term. The probability that a particular consumer will choose a particular alternative is given by the probability that the utility of that alternative to that consumer is greater than the utility to that consumer of all other available alternatives (Kennedy, 1996).

2. The probability of an individual selecting a given alternative is easily expressed, and
3. A likelihood function can be formed and maximized in a straightforward fashion.

The results for the multinomial logit model are reported in Table 4.1. Table 4.1 provides the coefficient, standard error, p-value, elasticities of probabilities, and the goodness of fit measures. The two coefficients are significant at the 0.05 probability level. To assess the fit of the model, two goodness-of-fit measures are reported. The two goodness-of-fit measures used in this model were the percentage of correct predictions and log-likelihood ratio test. The log-likelihood ratio test is given by $2*(\ln L_1 - \ln L_2)$ and is asymptotically distributed as a chi-squared random variable. The percentage of correct predictions is calculated as the total number of correct predictions as a percent of the number of observations. The results indicate the percentage of correct predictions and log-likelihood ratio test are 79.63% and -71.323 respectively. Furthermore, elasticities of probability indicated that class I and II recalls are inversely related with year of PR/HACCP implementation. A 1% increase in PR/HACCP implementation would decrease class I and II recalls by -.3912 and -.6525, respectively.

Second, the cost of recall (\$/plant) was computed using the average price of wholesale turkey multiplied by the monthly volume of food recall. However, volume of food recall comprises only one component of total cost of food recall; therefore, the other cost components of food recall including transportation cost, liabilities cost, and loss of market share were computed using the top 16 turkey processors in the United States.

Table 4.1. Parameter Estimates and Elasticities of Probabilities for Multinomial Logit Model

Dependent Variable	Independent Variable	Coefficient	Standard Error	P[Z] > z	Elasticities of Probabilities
Class I	YHACCP	-1.3291	0.3749	0.0004	-0.3912
Class II	YHACCP	-1.9169	0.4789	0.0001	-0.6525
Goodness of Fit Measures:					
LR Statistics		-71.323			
Percentage of Correct Predictions		79.63%			

The top 16 turkey processors in the United States account for 60% of the market share in the turkey industry. The total cost (\$/plant) was computed for each month from 1995-2003. The third step was to compute the adjusted benefit (\$/plant) for each month. In order to compute the adjusted benefit (\$/plant), elasticities of probabilities for Class 1 and 2 were multiplied by the monthly total cost of food recall. The fourth step was to change the adjusted benefit from (\$/plant) to (\$/lb). In this step, top 16 turkey processors processed on average certain amount of turkey each month from 1995-2003. The adjusted benefit (\$/lb) was computed by multiplying the average turkey processed (lb/plant) by adjusted benefit (\$/plant). In the fifth step, the sum of the adjusted benefit (\$/lb) for each year was computed from 1996-2003. Then, BestFitTM distribution tool was used to find the best distribution that fit the data from 1996-2003. This distribution provided the total risk reduction benefit from 1996-2003.

In order to compute the cost of PR/HACCP implementation, a triangular distribution was assumed for small, medium and large values, which are representative of the cost function (FSIS, 1996; Antle, 2000; Boland, Peterson, and Fox, 2001). Next, the economic impact of PR/HACCP implementation was computed by subtracting the total risk

reduction benefit of PR/HACCP (\$/lb) from the cost of PR/HACCP (\$/lb) assuming a triangular distribution. Finally, the results of the above procedures provided the net economic benefit of PR/HACCP at t period.

Thus, scenario 2 defined observed turkey processing margin and hypothetical margin, respectively, as

$$TPM_t = WPT_t - WCT_t \pm NHB_t, \quad (16)$$

where

TPM_t = Turkey processing margin in current period,

WPT_t = Wholesale price of turkey in current period,

WCT_t = Wholesale cost of turkey in current period, and

NHB_t = Net economic benefit of PR/HACCP in current period; and

$$HM_{t-1} = WPT_{t-1} - WCT_{t-1} \pm NHB_{t-1}, \quad (17)$$

where

HM_{t-1} = Hypothetical margin in previous period,

WPT_{t-1} = Wholesale price of turkey in previous period,

WCT_{t-1} = Wholesale cost of turkey in previous period, and

NHB_{t-1} = Net economic benefit of PR/HACCP in previous period.

In the final step, the hypothetical margin (\$/lb) was subtracted from observed margin (\$/lb) to calculate the monthly VaR with a 95% level of confidence. BestFit™ distribution tool was used to find the best distribution. Then, using @Risk™ software, the distribution was simulated 1,000 times and VaR at 95% confidence levels was calculated.

Scenario 3: Empirical Models and Procedures

In scenario 3, the observed and hypothetical net benefits of PR/HACCP are calculated with respect to the collected data from the small turkey processing plant. The analysis in this section was divided into two parts, generic and augmented CCPs, using 29%, 15%, and 5% tolerance levels to examine the impact of actual microbial count on the predicted VaR in both cases. The generic CCPs are mandatory under PR/HACCP plan; however, the augmented CCPs are the additional CCPs implemented by this plant in order to further prevent/reduce potential hazard occurrences along the line of production.

The generic CCPs mandated by FSIS regulation are Pre-Wash (CCP5) and Visual Inspection (CCP7). The augmented CCPs in this study are Pre-Scald (CCP1), Post-Scald (CCP2), Pre-Evisceration (CCP3), Post-Evisceration (CCP4), Post-Wash (CCP6), and Chill (CCP8). The eight CCPs identified in this study are

1. Pre-Scald,
2. Post-Scald: using hot water at 150⁰F,
3. Pre-Evisceration: cold water wash,
4. Post-Evisceration: cold water wash,
5. Pre-Wash: cold water wash,
6. Post-Wash: chlorinated rinse mixed with water,
7. Visual Inspection: CCP for fecal material, and
8. Chill: Temperature control.

The Net benefit of PR/HACCP in scenario 3 is defined as

$$NB_{PR/HACCP(t)} = TR_t + VRR_t - TC_t - QL_t - IC_t - FC_t, \quad (18)$$

where

$NB_{PR/HACCP(t)}$ = Net benefit of PR/HACCP in current period,

TR_t = Total revenue per month in current period,

VRR_t = Total value of risk reduction per month in current period,

TC_t = Total testing cost per month in current period,

QL_t = Total quality loss per month in current period,

IC_t = Total input cost per month in current period, and

FC_t = Total fixed cost per month in current period.

Definition and Procedures for Variables in Equation 18

Total Revenue. Total revenue is defined as

$$TR_t = WPT_t * NTP_t, \tag{19}$$

where

TR_t = Total revenue (\$/month),

WPT_t = Wholesale price of turkey (\$/lb), and

NTP_t = Number of turkey bird processed per month.

The number of turkey bird processed per month comprised of number of turkey processed per day, number of working days per month, and turkey weight.

Probability of Contamination. In order to calculate the value of risk reduction and quality loss at each CCP, the probability of contamination at CCPs must be calculated to reflect the risk of contamination. The probability of contamination is composed of the existing contamination of the turkey bird before arriving in the plant, as well as cross-contamination that may occur during processing.

In this study, 800 data samples of *Salmonella* were used to calculate the probabilities of contamination at each CCP. Due to the relatively small number of samples data collected from the small turkey processing plant, it was believed that results may not be representative of the level of contamination at each CCP. Therefore, using @Risk software, 1,000 data points were simulated for each CCP, and BestFit™ tool was used to assign the distribution for each data. The result of simulation suggested that an extreme value distribution was the BestFit™ distribution for data. Thus, extreme value distribution was used to calculate the different level of contamination at each critical limit.

The Probability of contamination at each Critical limit is defined as

$$P_c = \frac{N_a}{n}, \quad (20)$$

where

P_c = The probability of contamination at each CCP,

N_a = The number of values above the upper critical limit at each CCP, and

n = The sample size at each CCP.

This model is evaluated at critical limits for 29%, 15% and 5% level of pathogen contamination. It is important note that 29% level of pathogen contamination at each critical limit is the required amount by the FSIS.

Value of Risk Reduction. The value of risk of reduction is defined as

$$VRR = (P_c * P_t * T) * \beta, \quad (21)$$

where

P_c = The probability of contamination at a particular CCP,

P_t = The wholesale price of turkey,

T = The total turkey production per day, and

$\beta = (0,1)$ is the binary variable representing the decision to test/not test.

Value of risk reduction is the value received by the processor for deciding to test for pathogens at each CCP, and implement control measures. In this model, the two major sensitive variables impacting the value of risk reduction are the testing intensity and decision to test or not test. The testing intensity represents the number of samples taken at each CCP. On the other hand, the decision to test or not test was defined as a binary variable equal to 1 for testing and 0 for no test. To compute the value of risk reduction, we assumed a normal distribution which was based on the mean and standard deviation of the probability values.

Total Testing Cost. Total testing cost is defined as

$$TC_t = C_{CCP} + C_{Labor} + CT_{Salmonella}, \quad (22)$$

where

TC_t = Total testing cost,

C_{CCP} = Cost of CCP,

C_{Labor} = Cost of labor, and

$CT_{Salmonella}$ = Cost of *Salmonella* testing.

Testing cost may vary from plant to plant due to difference in labor, type of *Salmonella* testing or other costs. For example, according to statistics from the small turkey processing firm used in this study, the cost of one *Salmonella* test can range from \$10- \$14. Also, the salary of an employee in charge of food safety can vary from \$8- \$20 per hour depending on his or her experience. To make testing cost representative, we

assumed normal distributions for the cost of labor and cost of *Salmonella* testing. Table 4.2 presents the distributions for the three testing cost components.

Table 4.2. Distribution of Testing Cost Components

Testing Cost Components	Distribution	Parameters
Cost of one CCP		\$36.93
Cost of labor	Normal	Mean (\$14) & Stdev (\$6)
Cost of <i>Salmonella</i> testing	Normal	Mean (\$12) & Stdev (\$2)

Quality Loss. The quality loss function used in this study was based on the Taguchi loss function. Palisade Corporation (2001) defined the Taguchi loss function as a function that enables a plant to quantify its loss from poor product quality. The quality loss increases as a function of the square of the deviation from the nominal value, regardless of the location of the specific limits. Taguchi believes that customers become increasingly dissatisfied as performance departs from the targets.

The notion of tolerance in the Taguchi loss function is represented by the Lower Critical Limit (LCT) and Upper Critical Limit (UCT). The LCT and UCT represent the consumer tolerance level. Wilson, Jabs, and Dahl (2003) stated that, tolerance defines the maximum, minimum or range of desired target values, while costs include testing and market loss resulting from non-conformance. Figure 4.1 presents the Taguchi loss function and its characteristics.

The Taguchi loss function is traditionally represented as



Figure 4.1. Taguchi loss function.

$$L(y) = k(y-m)^2, \quad (23)$$

where

$L(y)$ = The quality loss function,

k = The adjustment factor (constant),

y = A single product quality characteristic, and

m = The desired target value.

The Taguchi loss function can be applied in two different situations: small-is-better and larger-is-better. The small-is-better and large-is-better can be modeled as

$L(y) = k(y)^2$ and $L(y) = \frac{1}{y}$, respectively. However, this study examined the Taguchi

loss function with smaller-is-better characteristic in which the target value is zero and no negative values are assumed. The Taguchi loss function is defined as

$$L = \frac{A_0}{2} * \sigma^2, \quad (24)$$

Δ_0

where

L = The Taguchi loss function with small-is-better characteristics,

Δ_0 = The imposed USDA upper tolerance limit,

A_0 = Welfare loss to society when upper tolerance limit is exceeded, and

σ^2 = The average variance for the distribution of pathogen counts at producer delivery points from a target value of zero.

Welfare loss in equation 13 is defined as

$$A_0 = D + P_m + (R * P_t), \quad (25)$$

where

A_0 = The welfare loss for the firm when the upper tolerance limit is exceeded,

D = The impact on consumer demand,

P_m = The impact on the turkey market price,

R = The recall cost, and

P_t = Wholesale price of turkey that are not sold because of outbreak.

The welfare loss is distributed among the eight CCPs used in this study. The main objective of the Taguchi loss function in equation 23 is to minimize total costs, which include the cost of testing and the quality loss of non-conformance to a target.

Input Variable and Fixed Cost. The input variable cost of turkey is defined as

$$IC_t = WCT_t * NTP_t, \quad (26)$$

where

IC_t = Input cost of turkey per month,

WCT_t = Wholesale cost of turkey (\$/lb), and

NTP_t = Number of turkeys processed per month.

The number of turkey birds processed per month is comprised of number of turkey processed per day, number of working days per month, and turkey weight.

The fixed cost of PR/HACCP plan is defined as

$$FC_t = \frac{FCE}{BPH}, \quad (27)$$

where

FC_t = Fixed cost of PR/HACCP plan (\$/lb),

FCE = Fixed capital expenditures, and

BPH = Bird processed through PR/HACCP plan (lb).

There were a few assumptions made in order to compute the fixed cost of PR/HACCP plan for a plant. We assumed that the life for PR/HACCP equipments are 5 years and hours worked per week by employee of the small turkey processing plant is 40. The mean expected value of fixed cost per plant according to USDA poultry slaughter and processing plants is \$593,850. The pound of bird processed through PR/HACCP plan was computed as

$$BPH = WPB * NDW * NTP, \quad (28)$$

where

BPH = Pound of bird processed through PR/HACCP plan (\$/lb),

WPB = Weight pound per bird,

NDW = Number of days worked over 5 year period, and

NTP = Number of bird processed per day.

The hypothetical or forecasted margins in scenario 3 followed the same procedure as the observed margin; however, the only difference is with the time lag. Below is the equation of the hypothetical net benefit

$$NB_{PR/HACCP(t-1)} = TR_{t-1} + VRR_{t-1} - TC_{t-1} - QL_{t-1} - IC_{t-1} - FC_{t-1}, \quad (29)$$

where

$NB_{PR/HACCP(t-1)}$ = Net benefit of PR/HACCP in previous period,

TR_{t-1} = Total revenue per month in previous period,

VRR_{t-1} = Total value of risk reduction per month in previous period,

TC_{t-1} = Total testing cost per month in previous period,

QL_{t-1} = Total quality loss per month in previous period,

IC_{t-1} = Total input cost per month in previous period, and

FC_{t-1} = Total fixed cost per month in previous period.

In the final step, the hypothetical net benefit (\$/lb) was subtracted from the observed net benefit (\$/lb) to calculate the monthly VaR with a 95% level of confidence. The BestFit™ distribution tool was used to find the best distribution. Then, using @Risk™ software, the distribution was simulated 1,000 times, and VaR at 95% confidence levels was calculated.

Out-of-Sample Testing for Robustness or Model Fitness

Out-of-sample testing was done in scenarios 1, 2, and 3 for confidence levels of 95% and 99% to ensure the robustness of the model. The two tests used in this model were the likelihood ratio test and the Z test. The likelihood ratio test determined if the desired coverage level corresponding to the given confidence level was equal to the number of observed violations. The Z test determined whether the model was biased in estimating

calculated VaR. The VaR can sometimes overestimate or underestimate the actual downside risk.

Sensitivity Analysis

One problem with VaR is the robustness of the results. There are several tests that can be use overcome this problem. For this study, backtesting was used to verify that the predicted VaRs were adequate in predicting the actual losses and did not overestimate or underestimate the actual downside risk. Also, extreme value theory¹⁶ can be use to test for robustness if backtesting shows that the predicted VaRs are not robust. It is important to note that the addition of extreme value distribution was not the result of backtesting failure. The backtesting results indicated that the estimated VaR did not overestimate or underestimate the actual downside risk. The best fit distribution was Loglogistic distribution not the extreme value distribution.

This study compares the VaR results under normal and abnormal market conditions. According to Linsmeier and Pearson (2000), VaR is a measure of losses due to “normal” market movements, and the estimated VaR does not tell us anything about the magnitude of losses in abnormal market conditions which can have significant profits or losses effects. Hinrichs and Odening (2003) stated that, historical simulation or variance/covariance method can fail when the return distribution is fat tailed. This problem is aggravated when long-term VaR forecasts are desired. Thus, extreme value distribution was introduced to capture abnormal market conditions and its impact on the characteristic and small turkey processing plant predicted VaR. Finally, results of the predicted VaR with Loglogistic distributions and ExtValue distributions were compared.

¹⁶ Extreme Value Theory is a statistical discipline to describe and understand quantifiable rare events. It is especially well suited to describe the heavy tails of win or loss distributions.

Parametric (RiskMetrics) method was also used to compare the predicted VaR results with that of the historical simulation. In this case, we want to examine whether both parametric (RiskMetrics) and full-valuation (historical simulation) methods produce similar results, and this would further validate the predicted VaR results used in this study.

Empirical Data: Three Alternative Scenarios

Table 4.3 presents the summary of the model variables and data sources.

Table 4.3. Summary of Data Sources Used in This Study

<u>Model Variables</u>	<u>Data Sources</u>
Wholesale prices of turkey (1995-2003)	Livestock, Dairy, and Poultry outlook, ERS
Wholesale cost of turkey (1995-2003)	Livestock, Dairy, and Poultry outlook, ERS
Type of food recall and volume of food recall (1995-2003)	FSIS
Cost of PR/HACCP	Boland, Peterson, and Fox (2001); FSIS (1996); and Antle (2000).
Total product of volume recall	FSIS
Transportation cost	Meat and Poultry Magazine (2003)
Liabilities cost	Rawson (2003)
Volume of turkey processed	Watt PoultryUSA (2004)

Table 4.4 presents the summary of the three stochastic variables. In Table 4.4, the years, distributions and parameters of the three stochastic variables are presented.

Table 4.5 provides two type of data sets used in this study: types of food recall and volume of food recall (lb). The period of this data ranged from 1995-2003. In this study, only Type 1 and 2 food recalls were used.

Table 4.4. Summary of Distributions/Parameters for Each Stochastic Variable

Years	Variables	Distributions	Parameter
1995-1999	Price	Normal	(0.65, 0.05)
1995-1999	Cost	BetaGeneral	(0.85, 1.31, 0.55, 0.78)
2000-2003	Price	Loglogistic	(0.44, 0.17, 6.73)
2000-2003	Cost	Weibull	(2.49, 0.04, RiskShift (0.55))
1996-2003	Net Economic Benefit of PR/HACCP	Invgauss	(0.02, 0.00, RiskShift (0.00))

Source: Economic Research Service (1995-2003).

Type 3 food recall was omitted from this study because it only occurred once during the period ranging from 1995-2003. The total volume of food recall for each year was collected representing the combination of type 1 and 2 food recalls.

Table 4.5. Type and Total Volume of Food Recall for Each Year

Year	Type of Food Recall	Volume of Food Recall (lb)
1995	1 & 2	3,214,724
1996	1	40,620
1997	2	62,000
1998	1	38,752
1999	1	34,910
2000	1 & 2	17,126,797
2001	1 & 2	26,175
2002	1 & 2	531,600
2003	1 & 2	12,085

Source: FSIS (1995-2003).

The costs of implementing the PR/HACCP system were taken from three different studies done on the cost effectiveness of implementing PR/HACCP. The smallest value was estimated by FSIS (1996); the medium value was estimated by Antle (2000); and the largest value was estimated by Boland, Peterson, and Fox (2001). The smallest, medium, and largest values for implementing PR/HACCP (\$/lb) are 0.0012, 0.004, and 0.009, respectively.

The liability cost reflects the average compensation for consumer plaintiffs in foodborne illness lawsuits. There were 178 court cases in the past decade in 3 categories that led to lawsuits.

The three major categories are

1. Cases involving a premature death,
2. Cases involving hospitalization but not a premature death, and
3. All other cases involving less severe illnesses (Rawson, 2003).

The cost of transportation due to food recall, on average, is assumed to be \$4 million over the past decade. The figure was assumed by the fact that the meat and poultry industry recorded transportation cost to be between \$2 million and \$10 million, depending on the size of the recall and product replacement (Kay, 2003).

Table 4.6 presents the top 16 turkey processors in the United States and their processed turkey production. The top 16 turkey processors in the United States used in this study are representative of the typical turkey processing plant because they make up 60% of all turkey processing productions in the United States. These data were used to compute the loss of market share by a characteristic turkey processing plant.

Table 4.6. Top 16 Turkey Processors in the United States

Turkey Processors	Live Weight* Processed (Million Pounds)
Cargill Turkey Products	1210
Jennie-O Turkey Store	1200
Butterball Turkey Co.	800
Carolina Turkeys	580
Pilgrims Pride	509
Louis Rich Turkey Co.	300
Sara Lee Refrigerated Foods	273
House of Raeford	250
Perdue Farms, Inc.	241
Foster Farms	233
Willow Brook Foods, Inc.	196
Farbest Foods	192
Cooper Farms	170
Michigan Turkey Producers	162
Norbest, Inc.	157
West Liberty Foods	155

Source: Watt Poultry (2004).

CHAPTER 5. RESULTS AND DISCUSSIONS

This chapter reports the results of the three empirical scenarios that demonstrated VaR methodology in Chapter 4. Scenario 1, prior to PR/HACCP implementation, focuses on the period in which the PR/HACCP system was not mandated for characteristic turkey processing plants. Scenario 2, after PR/HACCP implementation, models the period in which a characteristic turkey processing plant is required to implement the PR/HACCP system. In scenario 2, VaR was calculated based on the impact of PR/HACCP on food recall data due to microbial outbreak from 1996-2003. Scenario 3, under more stringent risk management strategies, focuses on the actual risk reduction benefit of PR/HACCP using the microbial count of a small turkey processing plant. Furthermore, results from the sensitive analysis are presented.

Objective 1

The VaR and standard deviation results for three scenarios are reported in Table 5.1. Scenario 3 results are divided into generic and augmented PR/HACCP with 29%, 15%, and 5% tolerance levels (TL). It is important to note that the mandatory TL is 29% (FSIS-USDA, 1996). The 15% and 5% TLs were used in the sensitive analysis to determine the impact TL has on the predicted VaR.

Scenario 1: Prior PR/HACCP Implementation

In scenario 1, the VaR portfolio was estimated using two stochastic variables: 1) wholesale price of turkey and 2) wholesale cost of turkey. The result in Table 5.1 shows that the VaR of characteristic turkey processing plants prior to PR/HACCP implementation from 1995-1999 was \$-0.06905 per lb. The VaR suggests that characteristic turkey processing plants, on average, were losing \$0.06905 per lb not more than 5% of the time in

any given month. In other words, we are 95% confidence that the predicted VaR would not exceed \$0.06905 per lb more than 5% of the time. The standard deviation of 0.04499 shows the spread or variability from the VaR realized by characteristic turkey processing plants from 1995-1999.

Table 5.1. Summary of VaR and Standard Deviation
(Monthly Turkey Processed= 2,288,000 lb)

Scenario	Description	Average VaR (\$/lb)	Standard Deviation
Scenario 1	Prior to PR/HACCP implementation (1995-1999)	-0.06905	0.04499
Scenario 2	After PR/HACCP implementation (2000-2003)	-0.04936	0.03175
Scenario 3	Generic PR/HACCP 29% TL	-0.04916	0.03091
	Augmented PR/HACCP 29% TL	-0.04991	0.02871
	Generic PR/HACCP 15% TL	-0.04889	0.03019
	Augmented PR/HACCP 15% TL	-0.04906	0.03043
	Generic PR/HACCP 5% TL	-0.04905	0.03041
	Augmented PR/HACCP 5% TL	-0.04996	0.02882

Scenario 2: After PR/HACCP Implementation

In Scenario 2, the VaR portfolio was estimated based on three stochastic variables: 1) wholesale price of turkey, 2) wholesale cost of turkey, and 3) net economic benefit of PR/HACCP system. The net economic benefit of PR/HACCP system was computed using

food recall data from 2000-2003 and the multinomial logit model. The result in Table 5.1 shows that the VaR of characteristic turkey processing plants after PR/HACCP implementation was \$ -0.04936 per lb. This VaR result suggests that characteristic turkey processing plants losses would not exceed \$-0.04936 more than 5% of the time in any given month. Standard deviation reported in Table 5.1 provides the variability or spread of the VaR.

Scenario 3: Under More Stringent Risk Management Strategies

The VaR results in this section were based on a small turkey processing plant. Microbial count was used to determine the actual risk reduction benefits of PR/HACCP system. The VaR for the generic and augmented PR/HACCP with 29%, 15%, and 5% TL are reported in Table 5.1. For example, VaR result for generic and augmented PR/HACCP with 29% T.L. are \$ -0.04916 and \$-0.04991, respectively. These results indicate that the characteristic turkey processing plant losses would not exceed \$ -0.04916 and \$-0.04991 respectively more than 5% of the time in any given month.

Comparison of Scenarios Results and Implications

This section begins with the comparison of results for the period prior to and after PR/HACCP implementation. The results also examine whether the hypothesis of this study that PR/HACCP implementations significantly reduces firm-level food safety risk and improve profitability is validated. Next, the results of scenario 3 are compared under 2 cases:

1. Generic 29% TL and
2. Augmented 29% TL.

Finally, graphical representations of the five cases in scenario 3 are presented.

Comparison of Scenario 1 and 2 VaR Results

The VaR results prior to PR/HACCP Implementation (scenario 1) shows that on average characteristic turkey processing plants were losing \$0.06905 per lb in any given month from 1995-1999. However, during post PR/HACCP implementation (scenario 2) characteristic turkey processing plants lost \$0.04945 per lb on average in any given month from 2000-2003. These results suggest that PR/HACCP can significantly food safety risk and improvement of profitability. Thus, these results also validate the hypothesis. In addition, these results further strengthen the argument made by policy makers who advocated that implementing PR/HACCP system, that it can significantly reduce food safety risk. However, it is important to note the policy makers' conclusions on PR/HACCP implementation was based on society level benefit not on firm-level benefits. Thus, this study focuses on firm-level benefit of implementing PR/HACCP system.

Figure 5.1 shows the monthly net margin (difference) of prior to and after PR/HACCP implementation. The figure suggests that prior to PR/HACCP implementation from 1995-1999, characteristic turkey processing plants experienced large fluctuations in net margin. After PR/HACCP implementation, characteristic turkey processing plants net margins improved from 2000-2003. This improvement of the net margins in 2000 slightly decreases after January 2001. However, the decrease of the net margins was stable and predictable compare to prior PR/HACCP implementation. It is important to note that this did not have data up to 2004 data; therefore, we can conclude whether net margins continue to increase/decrease.

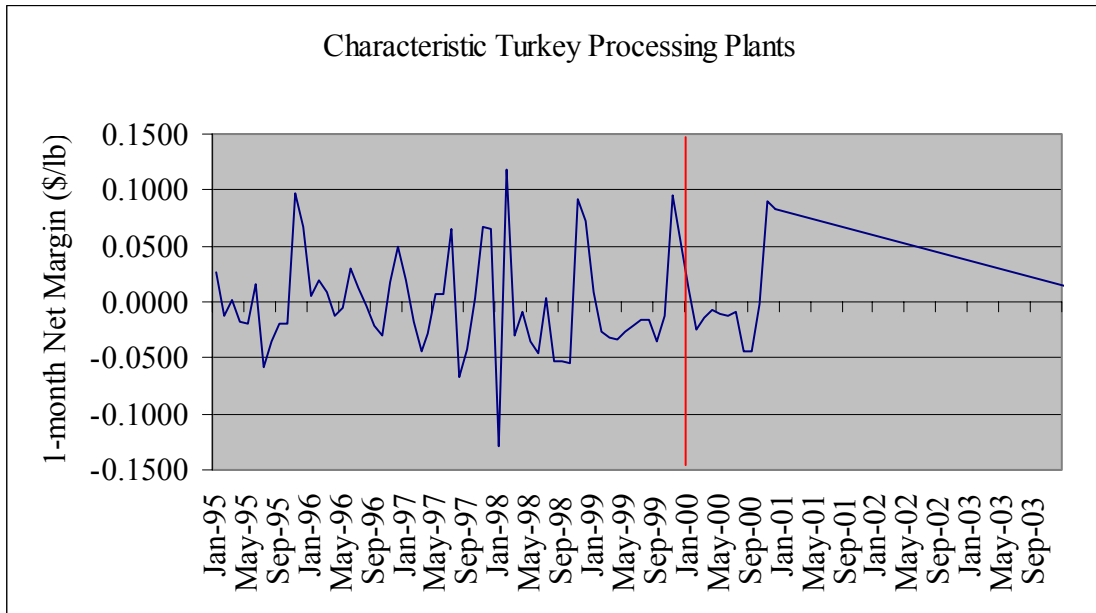


Figure 5.1. Monthly net margin prior to and after PR/HACCP implementation.

Comparison of Scenario 3 under Case 1 and 2

Using the small turkey processing plant data, the results of the generic PR/HACCP indicates that the plant was losing \$0.04916 per lb (29% TL) on average in any given month. However, the result slightly changed when the plant decided to implement the augmented PR/HACCP. The plant realized a lost of \$0.04991 per lb when the augmented PR/HACCP was implemented. These results validate that the generic and augmented PR/HACCP reduces firm-level food safety risk and improves profitability. Figure 5.2 provides a graphical representation of the small turkey processing plant monthly net margin under generic and augmented PR/HACCP with 29% TL from 2000-2003. This graph shows that both the generic and augmented monthly differences increase and decrease together. These results suggest that since the both the generic and augmented PR/HACCP move in the same direction, it is better to implement the augmented PR/HACCP because it

further reduces the contamination along the line of production; thus, achieving one of the objective/goal of PR/HACCP system.

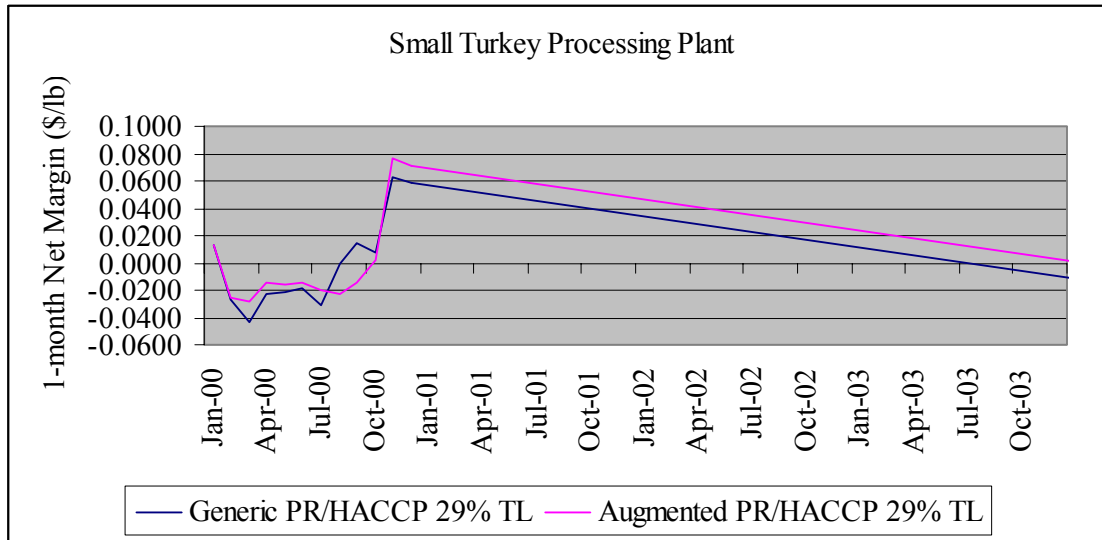


Figure 5.2. Comparison of monthly net margin for small turkey processing plant: generic and augmented PR/HACCP 29% TL.

Sensitivity Analysis

This section provides a brief explanation of sensitivity analysis conducted under four cases using scenario 3 results and one case using different VaR distributions. The five cases addressed in this section are

1. Generic and Augmented PR/HACCP with 15% TL;
2. Generic and Augmented PR/HACCP with 5% TL;
3. Generic PR/HACCP with 29%, 15%, and 5% TL;
4. Augmented PR/HACCP with 29%, 15%, and 5% TL; and
5. VaR results with Loglogistic vs. Extvalue distributions.

In addition, graphs comparing VaR measure for all five cases are presented. Finally, VaR estimates using RiskMetric Parametric methods are discussed.

Generic and Augmented PR/HACCP with 15% Tolerance Level (TL)

The results of the generic and augmented PR/HACCP provided in Table 5.1 suggest that as the tolerance level becomes more restricted, the small turkey processing plant realized a slight change by implementing the augmented PR/HACCP. These results may be due to the fact that as tolerance level becomes more restricted and level of turkey bird contamination declines, the VaR for the small turkey processing plant stabilizes. Figure 5.3 provides a graphical representation of the characteristic turkey processing plant monthly differences for the generic and augmented PR/HACCP with 15% TL from 2000-2003. Again, this graph shows that the monthly differences of the generic and augmented are moving in the same direction. Both the generic and augmented PR/HACCP monthly difference increased from January 2000-January 2001 and experienced a decrease from February 2001-November 2003.

Generic and Augmented PR/HACCP with 5% TL

The results of the generic and augmented PR/HACCP with 5% TL are reported in Table 5.1. There was slight change in the VaR for the small turkey processing plant when the augmented PR/HACCP was implemented. The implementation of the augmented PR/HACCP would further reduce the contamination along the line of production; thus, achieving one of the objective/goal of PR/HACCP system.

Figure 5.4 provides a graphical representation of the small turkey processing plant monthly generic and augmented PR/HACCP with 5% TL from 2000-2003. This graph indicates that both the generic and augmented monthly difference are moving in the same

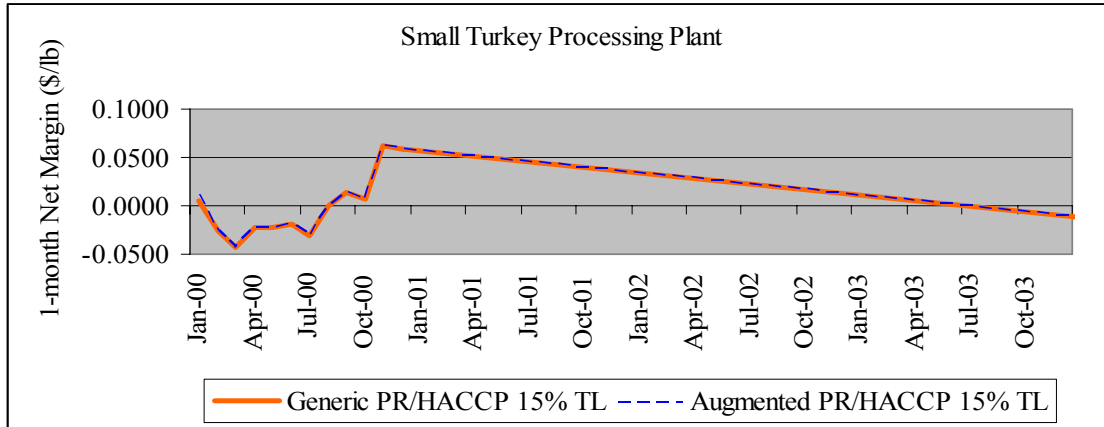


Figure 5.3. Comparison of monthly net margin for small turkey processing plant: generic and augmented PR/HACCP 15% TL.

direction and that there is only slight difference between the systems. To identify whether the VaR results in Table 5.1 are significantly different, a two-sample t-test was conducted (Table 5.2).

The Results in Table 5.2 suggest that the VaR prior to and after PR/HACCP are significantly different $\alpha=0.05$. The null hypothesis is rejected. However, the VaR results of the generic and augmented PR/HACCP with 29%, 15%, and 5% TL suggest that VaR results are not significantly different $\alpha=0.05$.

Generic PR/HACCP with 29%, 15%, and 5% TL

The results of generic PR/HACCP with 29%, 15%, and 5% TL suggests that more restricted tolerance levels are, the small turkey processing plant monthly differences does not change. In all three cases, the monthly difference increases sharply around January

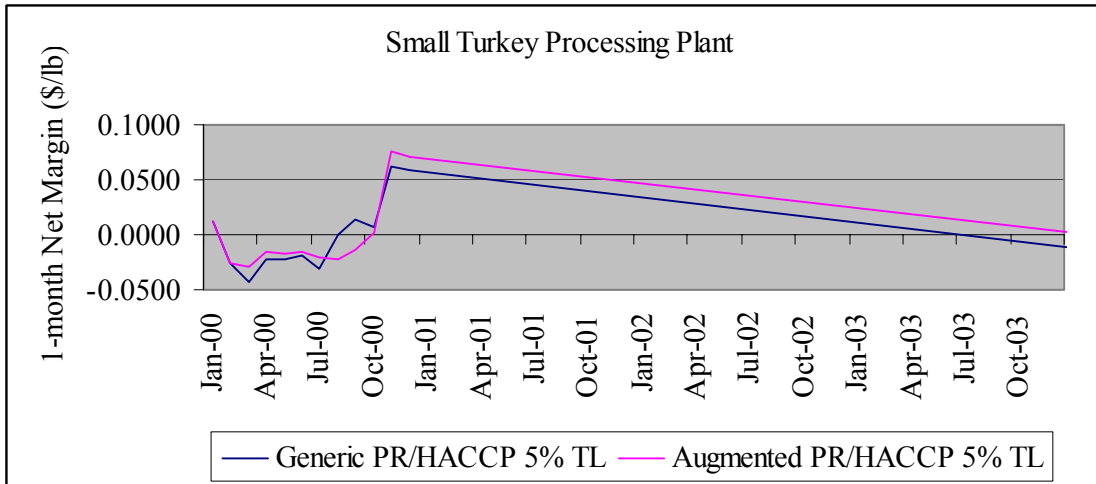


Figure 5.4. Comparison of monthly net margin for small turkey processing plant: generic and augmented PR/HACCP 5% TL.

Table 5.2. Two-Sample T-Test for VaR Results

Variable (B1)	Variable (B2)	t-value
1. Prior to PR/HACCP	After PR/HACCP	3.21608*
2. Generic PR/HACCP(29 % T.L)	Augmented PR/HACCP (29% T.L.)	0.168106
3. Generic PR/HACCP (15% T.L.)	Augmented PR/HACCP (15% T.L.)	0.039013
4. Generic PR/HACCP (5% T.L.)	Augmented PR/HACCP (5% T.L.)	0.207322

*Significant at the 5% level. The t-test critical value is 1.96.

2001 and decreases gradually from April 2001-November 2003. Figure 5.5 provides a graphical comparison of small turkey processing plant monthly generic 29%, 15% and 5% TL from 2000-2003.

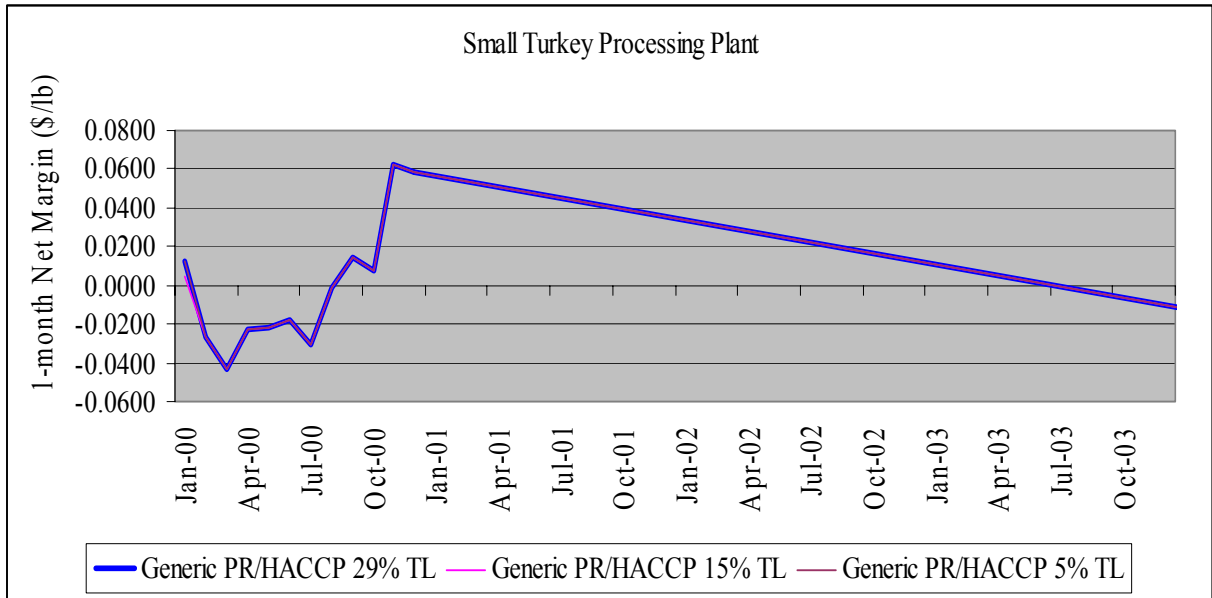


Figure 5.5. Comparison of monthly net margin for small turkey processing plant: generic 29%, 15%, and 5% TL.

Augmented PR/HACCP with 29%, 15%, and 5% Tolerance Level

These results suggest that as the tolerance levels become more restricted for the augmented PR/HACCP, they produce similar results. Thus, the benefit for a small turkey processing plant from implementing the augmented PR/HACCP increases. This concept can be validated in Figure 5.6. Figure 5.6 shows that the augmented PR/HACCP with 29% and 5% TL are changing together. However, the augmented PR/HACCP with 15% TL also increases and decreases from 2000-2003, but its monthly differences are less than the augmented PR/HACCP with 29% and 5% TL.

VaR Results with Loglogistic vs. ExtValue Distributions

In this section, the comparison of these results is made both in monthly VaR \$/lb and \$. These distributions are used to compare the VaR results under normal and abnormal market conditions. The results suggest that the VaR under normal and abnormal market

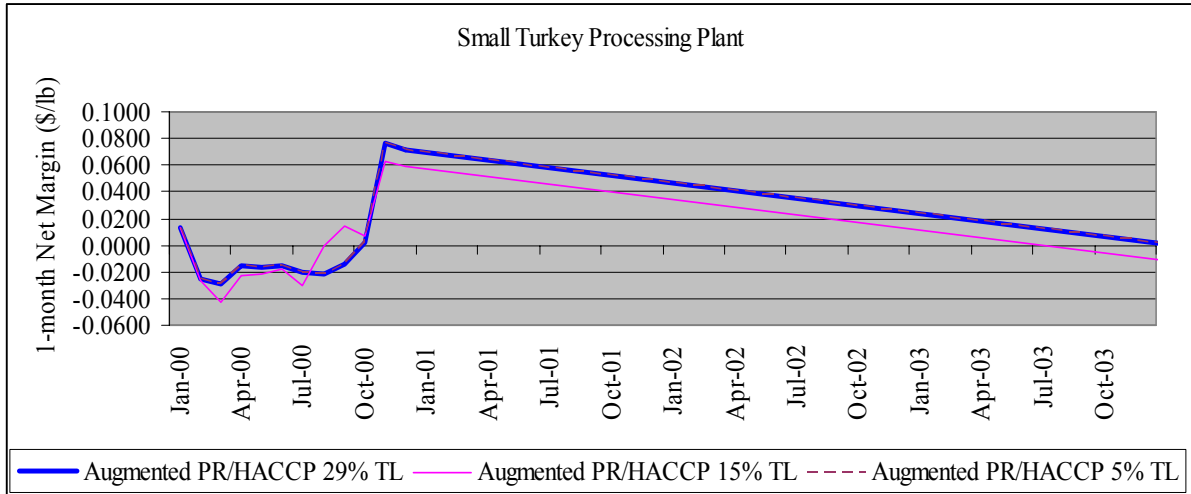


Figure 5.6. Comparison of monthly net margin for small turkey processing plant: augmented 29%, 15%, and 5% TL.

conditions are not significantly different. For example, Table 5.3 reports that, in scenario 1, the monthly VaR (\$) with Loglogistic and ExtValue distributions is -9,874 and -10,307, respectively. The monthly VaR(\$) under both distributions is only slightly different. The characteristic turkey processing plants should expect to lose not more than \$-10,307 with 5% in any given month even under abnormal market conditions. VaR results for scenarios 2 and 3 are also provided (Table 5.3). Under both distributions, the results are also slightly not different. It is important to note that firm-level management is more concerned with abnormal market conditions because their impact can significantly affect the plant's profit. Therefore, firm-level management may use these results to implement alternative risk management tools to further reduce the predicted VaR under these abnormal market conditions.

Finally, Table 5.4 reports parametric (RiskMetrics) VaR results at $\lambda=.97$ and $\lambda=.94$ decay factors.

Table 5.3. VaR with Loglogistic and ExtValue Distributions
(Monthly Volume Processed=2,288,000 lb)

Scenario	Description	Monthly VaR (\$/lb) Loglogistic Distribution	Monthly VaR (\$) Loglogistic Distribution	Monthly VaR (\$/lb) ExtValue Distribution	Monthly VaR (\$) ExtValue Distribution
Scenario 1	Prior to PR/HACCP Period (1995-1999)	-0.06905	-9,874	-0.07208	-10,307
Scenario 2	After PR/HACCP Period (2000-2003)	-0.04936	-7,059	-0.05555	-7,942
Scenario 3	Generic PR/HACCP 29% TL Level	-0.04916	-7,029	-0.05211	-7,452
	Augmented PR/HACCP 29% TL	-0.04991	-7,137	-0.05198	-7,433
	Generic PR/HACCP 15% TL	-0.04889	-6,990	-0.05209	-7,448
	Augmented PR/HACCP 15% TL	-0.04906	-7,015	-0.05210	-7,449
	Generic PR/HACCP 5% TL	-0.04905	-7,014	-0.05206	-7,444
	Augmented PR/HACCP 5% TL	-0.04996	-7,143	-0.05209	-7,448

These results indicate that prior to PR/HACCP implementation, small turkey processing plants were losing \$ -4,783 ($\lambda=.97$) and \$-5,294 ($\lambda=.94$). However, after PR/HACCP implementation, small turkey processing plants experienced large decrease in its VaR of \$-1,965 ($\lambda=.97$) and \$-1,812 ($\lambda=.94$). These results further validate this study hypothesis that implementing PR/HACCP system can significantly reduce food safety risk and improve

profitability. Both parametric (RiskMetrics) and full-valuation (historical simulation) method suggest that implementing PR/HACCP can reduce food safety risk and improve small turkey processing plants profitability.

Table 5.4. Parametric (RiskMetrics) Method VaR Results

Scenario	Description	Monthly VaR(\$/lb), $\lambda=.97$	Monthly VaR(\$), $\lambda=.97$	Monthly VaR(\$/lb), $\lambda=.94$	Monthly VaR(\$), $\lambda=.94$
Scenario 1	Prior to PR/HACCP implementation	-0.0030	-4,783	-0.00335	-5,294
Scenario 2	After PR/HACCP implementation	-0.00133	-1,965	-0.00122	-1,812

Objective 2

Table 5.5 presents the out-of-sample test results for the three scenarios with 95% confidence level. The out-of-sample was conducted using likelihood ratio test and Z tests. Scenario 3 was divided into generic and augmented PR/HACCP with 29%, 15%, and 5% TL.

Out-of-Sample Test Results

The results in Table 5.5 indicate that both the LR statistic of 1.803 (3.841) and Z statistic -1.165 (1.96) in scenario 1 are not significance at 5% level. The LR statistic suggests that the actual portfolio losses did not exceed the predicted VaR more than 5% of the time in any given month. In other words, the predicted VaR fail to reject the null hypothesis that the number of violations realized over the period equals the number of implied by the predetermined confidence level ($\delta = \delta^*$). The Z test is also not significant

suggesting that predicted VaR did not overestimate the actual downside risk. In addition, Table 5.5 also reports the out-of-sample test results for scenario 2 and 3. In both cases, the results suggest that LR and Z statistics are not significant at the 5% level. These results indicate that the predicted VaRs were adequate in predicting actual losses and did not overestimate the actual downside risk.

Table 5.5. Out-of-Sample Test for the 95% Confidence Level

Scenario	Description	LR Statistic	Z Statistic
Scenario 1	Prior to PR/HACCP implementation (1995-1999)	1.803	-1.165
Scenario 2	After PR/HACCP implementation (2000-2003)	0.058	-0.234
Scenario 3	Generic PR/HACCP 29% TL	1.032	-0.904
	Augmented PR/HACPP 29% TL	1.032	-0.904
	Generic PR/HACCP 15% TL	1.032	-0.904
	Augmented PR/HACCP 15% TL	1.032	-0.904
	Generic PR/HACCP 5% TL	1.032	-0.904
	Augmented PR/HACCP 5% TL	1.032	-0.904
	Generic PR/HACCP 5% TL	1.032	-0.904
	Augmented PR/HACCP 5% TL	1.032	-0.904

*Significant at the 5% level. The Chi-squared critical value is 3.84.

**Significant at the 5% level. The critical Z value is 1.96.

Table 5.6 presents the out-of-sample test results for the three scenarios with 99% confidence level. The out-of-sample test was conducted using Likelihood ratio test and Z tests. Scenario 3 was divided into generic and augmented PR/HACCP with 29%, 15%, and 5% tolerance levels.

The results in Table 5.6 indicate that both the LR statistic of 0.238 (6.635) and Z statistic 0.536 (2.576) are not significant at 1% level. The LR statistic suggests that the actual portfolio losses did not exceed the predicted VaR more than 1% of the time in any given month. The predicted VaR fail to reject the null hypothesis that the number of violations realized over the period equals the number of implied by the predetermined confidence level ($\delta = \delta^*$). The Z test is also not significant suggesting that predicted VaR did not underestimate the actual downside risk. In addition, Table 5.6 also presents results of scenario 2 and 3 for the LR statistic and Z test. In both cases, the results suggest that LR and Z statistics are not significant at the 1% level.

Objective 3

Implications for Management

This study focused on the turkey industry. In 2003, turkey as a food commodity amounted for \$2.72 billion in US total production value. Previous studies suggested that among chickens, eggs, broilers and turkey, *Salmonella* contamination of ground turkey is highest at 49% prior to PR/HACCP implementation and 26% after PR/HACCP implementation. This suggests that turkey processing is suited for PR/HACCP impact studies.

VaR provides a framework for assisting firm management in assessing food safety risks in monetary terms and evaluating the effectiveness of control measures like

Table 5.6. Out-of- Sample Test for the 99% Confidence Level

Scenario	Description	LR Statistic	Z Statistic
Scenario 1	Prior to PR/HACCP implementation (1995-1999)	0.238	0.536
Scenario 2	After PR/HACCP implementation (2000-2003)	2.784	2.243
Scenario 3	Generic PR/HACCP 29% TL	0.456	0.777
	Augmented PR/HACCP 29% TL	0.456	0.777
	Generic PR/HACCP 15% TL	0.456	0.777
	Augmented PR/HACCP 15% TL	0.456	0.777
	Generic PR/HACCP 5% TL	0.456	0.777
	Augmented PR/HACCP 5% TL	0.456	0.777
	Generic PR/HACCP 5% TL	0.456	0.777
	Augmented PR/HACCP 5% TL	0.456	0.777

*Significant at the 1% level. The Chi-squared critical value is 6.635.

**Significant at the 1% level. The critical Z value is 2.576.

PR/HACCP. Also, turkey processors can better understand the use of VaR as a risk measurement and management tool in that VaR focuses on the downside risk and it is reported in dollars terms.

The results of this study provide three important management implications. First, the results indicate that VaR is effective in predicting food safety losses incurred by characteristic and small turkey processing plants. Firm management of turkey processing plants can use VaR to measure the downside risk and overcome a major challenge of

quantifying intangible benefits of a food safety system like PR/HACCP. Second, the results show that food safety losses declined significantly after PR/HACCP implementation. This result provides justification for increased investment in preventive measures like PR/HACCP. Third, the results suggest that losses incurred by small turkey processing plants under generic and augmented PR/HACCP were not significantly different. Firm management for a small turkey processor is better off with augmented PR/HACCP because it can further reduce contamination along the line of production, thus achieving one of the objectives of the PR/HACCP system.

Furthermore, policy makers must verify the benefit of regulatory requirement before implementing a system like PR/HACCP. The FSIS-USDA (1996) stated that regulating food safety with PR/HACCP programs constitutes a major rule under both the Executive Orders¹⁷ and the Regulatory Flexibility Act.¹⁸ For example, FSIS cost-benefit analysis of mandatory PR/HACCP implementation was based on effect at the level of society. However, the results of this study can provide policy makers with firm-level benefits of implementing PR/HACCP system; thus, justifying its significance to the reduction of the overall food safety risks.

¹⁷ Executive Orders or acts protect businesses against costly, regulatory procedures. Its also compels agencies to use cost-benefit analysis as a component of decision making.

¹⁸ Regulatory Flexibility Act requires regulatory relief for small businesses where feasible.

CHAPTER 6. CONCLUSIONS

This chapter provides brief summaries of the problem addressed, objectives, and methodology. Summaries of results are also presented under three alternative scenarios which include 1) prior to PR/HACCP implementation, 2) after PR/HACCP implementation, and 3) under more stringent risk management strategies. Management implications from the results under the alternative scenarios are discussed. Finally, Study Limitations and Implications for Further Study are presented.

Summary of Problem

Food safety risk and the occurrence of foodborne illnesses became a major concern in the United States over the past decade. Approximately 4,000 deaths per year are blamed on foodborne illnesses attributable to contamination in meat and poultry products. Food recalls have caused the meat and poultry industry billions of dollars. To prevent/control the growing number of microbial outbreaks, the FSIS-USDA (1996) proposed the final rule to implement the PR/HACCP system.

All meat and poultry plant sizes were to adopt PR/HACCP systems by 2000 (FSIS, 1996). This system was introduced to ensure public safety from foodborne illnesses and to help meat and poultry plants control/reduce losses incurred by food recalls, defects, and liabilities. Additional benefits of the PR/HACCP system include longer product shelf life, greater reliability for consumers, and access to new markets, especially international markets (Unnevehr and Roberts, 1996). However, the cost of implementing PR/HACCP versus its benefit is still controversial, especially for small plants.

Summary of Objectives

The main objective of this study was to determine the risk reduction capabilities and performance of PR/HACCP systems. In order to achieve this objective, we used VaR methodology. VaR is used to predict food safety losses incurred by characteristic and small turkey processing plants prior to and after PR/HACCP implementation. In particular, this study evaluated the abilities/effectiveness of VaR to predict food safety losses; the impact of PR/HACCP on the predicted VaR; and the use of VaR as a management risk tool for firm managers and policy makers. These objectives employ unique techniques like the Z and likelihood ratio statistics to determine the robustness of VaR estimates. This study will help firm-level managers quantify the benefits of PR/HACCP system in monetary terms.

Summary of Methodology

The concept of VaR became popular as a risk analysis and management tool among financial institutions in the late 1980's due to market uncertainty about their trading portfolios. The proliferation of derivative instruments and the associate complexity of measuring risk have led to the demand for a portfolio-level quantitative measure of market risk (Linsmeier and Pearson (2000). Financial institutions or financial investors do not only embrace VaR, but so do regulators (Manfredo and Leuthold, 2001). Despite the increased use of VaR as a risk analysis and management tool by financial institutions, financial investor and regulators, its implementation in the agricultural sector is limited (Hawes, 2003).

VaR as a risk analysis and management tool has three main advantages. First, VaR reports risk in monetary term as a single summary statistic. This provides firm managers

who are not well versed in statistics a relatively simple means by which to estimate losses in dollar terms, especially when the distribution is non-normal. The assumption of normal distribution of market factors can provide bias estimates because market factors are constantly changing. Second, VaR provides the holding periods and probability levels used to predict large losses. Third, VaR only focuses the downside risk.

There are two primary methodologies used to compute VaR: parametric and full-valuation. The parametric method assumes market factors to have a multivariate normal distribution. However, its restriction of assuming a normal distribution of market factors can distort VaR estimates of portfolios. Full-valuation methods attempt to model the entire return distribution instead of providing a point estimate of volatility (Manfredo and Leuthold, 2001). This method is divided into historical and Monte Carlo simulations. Historical simulation is the simplest of the full-valuation procedures. It exposes the current portfolio to the prevailing price movements observed over a historical time period. In addition, historical simulation is flexible, easy to implement and does not assume a normal distribution. Finally, Monte Carlo simulation is a more complex of the full-valuation methods. It uses a pseudo random number generator and generates pseudo-random values of the risk factors of the portfolio based on a predetermined data generating process. Also, Monte Carlo is the most flexible of the VaR estimates. Of the three methodologies use to compute VaR, this study uses historical simulation.

Summary of Results

Scenario 1: Prior to PR/HACCP Implementation

To evaluate the effectiveness of the VaR methodology in predicting food safety losses attributable to food recalls by characteristic turkey processing plants, scenario 1 was

developed. In scenario 1, the wholesale price and cost of turkey from 1995-1999 were used to compute observed and hypothetical margins. The differences between observed and hypothetical margins were used to compute the VaR. In addition, the out-of-sample test was conducted both at the 95% and 99% levels to determine the robustness of VaR estimates.

The results indicate that prior to PR/HACCP implementations, characteristic turkey processing plants were losing \$-0.06905 per lb on average. The out-of-sample test using the likelihood ratio and Z tests were not significant at the 95% and 99% levels. This implies that actual portfolio losses did not exceed the predicted VaR and the predicted VaR did not overestimate the downside risk. Furthermore, the stress testing procedure indicated that predicted VaR under normal market conditions (\$-0.06905/lb) changed slightly under abnormal/extreme market conditions (\$-0.07208/lb). This result suggests that the predicted VaR adequately captured the downside risk for characteristic turkey processing plants.

Scenario 2: After PR/HACCP Implementation

In scenario 2, VaR methodology was used to evaluate its effectiveness in predicting food safety losses attributable to food recalls by characteristic turkey processing plants. The calculations of the observed and hypothetical margins differ slightly from scenario 1. The observed and hypothetical margins introduced the net economic impact of PR/HACCP in addition to the wholesale price and cost of turkey from 2000-2003. The out-of-sample test with 95% and 99% confidence levels was conducted to test the robustness of VaR estimates.

During this period, characteristic turkey processing plants were losing \$ -0.04936 per lb on average. This result suggests that the losses incurred by the characteristic turkey

processing plants declined in scenario 2 as compare to scenario 1. Also, the out-of-sample test for the 95% and 99% confidence levels were not significant implying that actual portfolio losses did not exceed the predicted VaR and the predicted VaR did not overestimate the downside risk. Finally, the stress test also indicated that the results under normal (\$-0.04936/lb) and abnormal (\$-0.05555/lb) market conditions changed slightly. Overall, the predicted VaR was adequate in predicting large losses for characteristic turkey processing plants.

Scenario 3: Under More Stringent Risk Management Strategies

Scenario 3 was developed because we did not know whether the results in scenarios 1 and 2 reflected structure changes that may have occur in the turkey industry. In this scenario, a small turkey processing plant was used to account for the actual risk reduction benefit of PR/HACCP. The generic and augmented PR/HACCP with 29%, 15%, and 5% TL were used for sensitive analysis. The net benefit of PR/HACCP was computed using the following total variables: revenue, value of risk reduction, testing cost, quality loss, input cost and fixed cost. Also, the out-of-sample test (95% and 99% confidence levels) and stress tests were conducted.

The results suggest that the losses incurred by the small turkey processing plant under generic and augmented PR/HACCP for 29%, 15%, and 5% TL were not significantly different. It is important to note that implementing augmented PR/HACCP is more costly than the generic PR/HACCP. However, the benefits increase proportionately with costs. Large and medium turkey processors would benefit more from implementing an augmented PR/HACCP plan than a generic PR/HACCP plan. Also, the out-of-sample test was not significant suggesting that actual portfolio losses did not exceed the predicted VaR and the

predicted VaR did not overestimate the downside risk. Finally, the stress test reflecting the normal (\$-0.04916/lb) and abnormal (\$-0.05211/lb) market conditions changed slightly under the generic PR/HACCP with 29% TL. The results were similar with the generic and augmented PR/HACCP with 15% and 5% TL. This indicates that the predicted VaR was adequate in predicting large losses for the small turkey processing plant.

Study Limitations

This thesis provides explanation of how VaR could be used by turkey processor in predicting food safety losses attributable to food recalls in monetary terms, and to evaluate the effectiveness of control measures like PR/HACCP. However, this study was limited by availability of data for 2004.

The analysis of prior to and after PR/HACCP implementation ranged from 1995-1999 and 2000-2003 respectively. However, the wholesale price and cost of turkey were not available for 2004. Therefore, we could not tell whether the trend of the current study results would be affected. Another limitation of this study is that not all the benefits of PR/HACCP like increased shelf life and access to new markets, especially international markets, can be capture directly with VaR. Finally, this study did not address the level of acceptable VaR. The level of acceptable VaR would depend on the plant objectives

Implication for Further Study

In all three alternative scenarios, the focus was on the effectiveness of VaR in predicting food safety losses attributable to food recalls and to evaluate the effectiveness of PR/HACCP as a control measure. However, it would be interesting to examine the impact of food safety insurance on firm-level profitability and its impact on the reduction of food safety risk. Also, it would be interesting to determine whether food safety insurance has a

significant impact on the predicted VaR. Furthermore, a comparison of food safety insurance versus the implementation of PR/HACCP system would provide us with cost-benefit analysis necessary to understand the reasons turkey processors, especially small turkey processors prefer food safety insurance as oppose to PR/HACCP system. Finally, a development of new methods to capture the benefits of PR/HACCP like increased shelf life and access to new markets, especially international markets, with VaR are encouraged.

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