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Value-at-Risk and Food Safety Losses in Turkey Processing

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Abstract

Food safety risks and microbial outbreaks have significant health impacts on society as a whole, as well as economic loss to food processing firms. According to the U.S. Centers 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). The U.S. Department of Agriculture, Food Safety and Inspection Services (USDA-FSIS) (1996) estimated that approximately 4,000 deaths each year are attributed to contamination in meat and poultry products. For food processing firms, microbial outbreaks often result in significant economic losses: food recalls, lost market share, and decreased consumer confidence. The intangible nature of aggregate economic losses makes it difficult for firm managers to predict firm-level economic impacts of food safety losses and adopt effective risk mitigation strategies. Developments in Value-at-Risk (VaR) methods provide an analytical framework to resolve this problem. This report develops VaR models to predict food safety risks in turkey processing, under alternative risk mitigation strategies.

The FSIS records of food recalls from 1994 to 2003 indicated that as much as $1.35 billion in losses were realized in the turkey industry. The objective of this report is to determine the firm-level risk reduction capabilities and performances of Pathogen Reduction/Hazard Analysis and Critical Control Point (PR/HACCP) systems using VaR and out-of-sample testing for robustness of findings. The VaR results suggest 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 the period prior to PR/HACCP implementation. However, after PR/HACCP implementation, turkey processing plants were losing $0.04936 per lb. In the period after PR/HACCP implementation, losses incurred under generic and augmented PR/HACCP for the small turkey processing plant were not significantly different. The out-of-sample tests indicated that VaR was adequate in predicting firm-level food safety economic losses. The results of this report provide private and public policymakers with alternatives to improve PR/HACCP implementation.

Key Words: PR/HACCP, Value-at-Risk, *Salmonella*, Turkey Processing

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Introduction

Food safety risk and microbial outbreak have significant health impacts on society as a whole, as well as economic loss to food processing firms. According to the U.S. Centers 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). The U.S. Department of Agriculture, Food Safety and Inspection Services (USDA-FSIS (1996) estimated that approximately 4,000 deaths each year are attributed to contamination in meat and poultry products. For food processing firms, microbial outbreaks often result in significant economic losses: food recalls, lost market share, and decreased consumer confidence. The intangible nature of aggregate economic losses makes it difficult for firm managers to predict firm-level economic impacts of food safety losses and adopt effective risk mitigation strategies. Developments in Value-at-Risk (VaR) methods provide an analytical framework to solve this problem. This report uses VaR models to predict food safety risks in turkey processing, under alternative risk mitigation strategies.

Turkey is an important food commodity whose total value of U.S. production amounted to $2.72 billion in 2003. While total turkey production accounted for only 12% of total production of broilers, eggs, turkeys, and chickens, studies by Rawson (2003) suggest that *Salmonella* contamination of ground turkey is highest at 49.9% prior to PR/HACCP implementation and 26.6% after PR/HACCP implementation. Buzby et al. (1998) noted that the number of cases of contamination with *Salmonella* alone range between 0.8 and 4 million people and between 1,000 and 2,000 deaths each year. In addition, the FSIS records of food recalls from 1994 to 2003 indicated that as much as $1.35 billion in losses were realized in the turkey industry. This suggests that processed turkey constitutes a prime commodity for PR/HACCP impact studies.

To mitigate health and firm-level economic losses, the USDA-FSIS on July 25, 1996, published a final rule for 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 USDA-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);

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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 the PR/HACCP system would range annually from $1.9 to 171.8 billion in 1995. However, the challenge is to quantify the intangible benefits of PR/HACCP versus its cost of implementation.

The goal of this report is to determine the risk reduction capabilities and performance of the PR/HACCP systems. More specifically, the three objectives of this report 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 the 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 policymakers to better understand the use of VaR as a risk measurement and management tool for food safety risk.

Food Safety Risk and Pathogen Reduction/Hazard Critical Control Point (PR/HACCP)

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 hazards 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 based on:
    a. severity (illness, magnitude, and duration) and
    b. likely occurrence (experience, epidemiological data, and information from the technical literature).

2. Determine Critical Control Point (CCP):[1] Controls will only relate to safety, not quality.
3. Establish critical limits: Risk assessment, 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 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.
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.

The benefits of the PR/HACCP system can be directly evaluated at the firm-level. For example, the potential benefits from implementing the PR/HACCP system are (Unnevehr and Roberts, 1996) longer product shelf life; access to new, distant markets, including international markets; greater reliability to consumers; and reduced produce recalls, defects, and liability. In monetary terms, the benefits of the PR/HACCP system should exceed the cost of implementing it. However, the challenge is to quantify the benefits. The benefit of the PR/HACCP system ranges from $1.9 billion to $171.8 billion annually (Crutchfield et al., 1997).

Performance data on the PR/HACCP system, combined with USDA-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 shows the decrease in *Salmonella* levels from 1998 to 2002 for selected meat and poultry products. However, despite the decrease in pathogen levels after the implementation of PR/HACCP, causality between the PR/HACCP system and the improvement of health/firm-level benefit is still controversial.

The cost of implementing the PR/HACCP system differs from firm to firm. PR/HACCP cost has two major components: Implementation costs and operating costs. Implementation costs include three main components: Plan development cost; training costs; and material,
building, and equipment costs. Operating costs include three main components:

1. Recordkeeping costs,
2. USDA verification cost, and
3. Bacteria testing.

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

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

Table 1. Decreased *Salmonella* Level for Selected Meat and Poultry Products

Products	Prior to HACCP Implementation	After HACCP Implementation
Young chickens	20.0%	10.0%
Market hogs	8.7%	4.7%
Cows and bulls	2.7%	2.2%
Steer and heifers	1.0%	0.4%
Ground beef	7.5%	3.2%
Ground chicken	44.6%	19.8%
Ground turkey	49.9%	26.6%

Source: Rawson (2003).

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 important in determining the difficulty in measuring the cost effectiveness of the PR/HACCP system for different firm sizes (large, medium, and small). The PR/HACCP system 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).

Despite the decrease of *Salmonella* level after PR/HACCP implementation, 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 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. Table 2 shows the rate of entry and exit of U.S. federally inspected meat slaughter plants from 1996-2003.

Table 2. Percentage Rates of Entry and Exit of U.S. Federally Inspected Meat Slaughter Plants

	Entry Rates (%)		Exit Rates (%)	
PR/HACCP Sizes	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).

Value-at-Risk (VaR) and Food Safety Losses

In the past decade, the use of 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 framework 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 front and back offices. Thus, the process for deriving VaR may be as important as the number itself. Nevertheless, VaR is undoubtedly here to stay (Jorion, 1996).

There are several advantages for using VaR as a risk measurement and management tool. These advantages include:

1. VaR gives managers the ability to think of risk in monetary terms instead of risk being classified with respect to standard deviation.
2. Upper managers who may or may not have a statistical background viewed VaR as an easier tool to estimate or predict losses in dollar terms.
3. VaR focuses on the downside risk.
4. 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).

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 an agriculture context include:

1. Manfredo and Leuthold (2001) used VaR to predict market risk and cattle feeding margins;
2. Garci, Roh, and Leuthold (1995) used VaR to simultaneously determine time varying hedging ratios in the soybean complex; and

3. Tzang and Leuthold (1990) used VaR to determine hedge ratios under inherent risk reduction in a commodity complex.

There are two methods used to compute VaR. These are parametric and full-valuation. However, this report focused on the full-valuation method to compute the monthly VaR. The full-valuation method is divided into historical and Monte Carlo simulations. However, the historical simulation was used to compute the monthly VaR for the characteristic and small turkey processing plant.

There are several advantages for using historical simulation to compute the monthly VaR for the characteristic and small turkey processing plant. The three specific advantages of historical simulation include:

1. It does not rely on distributional assumptions, so deviations from normality are not a problem (Linsmeier and Pearson 1996; Mahoney, 1995);
2. The distribution is valid for discrete or continuous data and fat or thin tails; and
3. The method is easy to understand by management.

The theoretical framework of VaR full-valuation method is presented as follows: VaR can be derived from the probability distribution for the future portfolio value where (Jorion, 1996)

$$c = \int_{W^*}^{\infty} f(w)dw, \qquad (1)$$

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

$$1\text{-}c = \int_{-\infty}^{W^*} f(w)dw. \qquad (2)$$

Future portfolio value is defined as f (w) and c is defined as the confidence level at a given time. Equation 2 also implies 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.

VaR is used to predict the monthly losses incurred by the 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 the @Risk™ software package and stochastic simulation techniques. Secondary data on net processing margins for the characteristic turkey processing plant, prior to (1995-1999) and after (2000-2003) PR/HACCP implementation are used for the analysis. To quantify the actual reduction benefit of PR/HACCP implementation, we identified major Critical Control Points (CCPs) and collected primary data from a small turkey processing plant which has been in operation since the 1930s. The primary data included actual microbial count, total testing cost, and the number of turkey birds processed.

Empirical VaR Model and Estimation Procedures

Three scenarios are developed to evaluate the effectiveness of VaR methodology in predicting food safety losses attributable to food recalls and microbial outbreak incurred by the 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 the characteristic turkey processing plant. Scenario 2 focuses on the period after PR/HACCP implementation by the 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 the 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 the small turkey processing plant.

In scenario 1, the period ranging from 1995 to 1999 represented prior to PR/HACCP implementation. During this period, the 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 prior to PR/HACCP implementation using historical VaR methodology. The period after PR/HACCP implementation ranged from 2000 to 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 the characteristic turkey processing plant using historical VaR methodology.

Scenario 1 examined the impact of food recalls on the characteristic turkey processing plant's profitability during non-mandatory PR/HACCP implementation from 1995 to 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 the characteristic turkey processing plant, 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 the number of food recalls and the plant's 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 the characteristic turkey processing plant's 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 generic[2] and augmented[3] PR/HACCP systems.

Analytical Procedures

In order to estimate the statistical distributions of the data used in the model, the 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 the 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 use are chi-squared,[4] Kolmogorov-Smirnov,[5] and Anderson-Darling.[6] The fit statistic with the lowest number is selected as the best fit distribution. However, the choice

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

[3] Augmented PR/HACCP is the additional CCPs implemented by turkey processing plants to further reduce the risk of contamination along the line of production. They are not mandated by USDA-FSIS regulation.

[4] 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, 1975).

[5] 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).

[6] Anderson-Darling test involves graphical transformations of the Cumulative Density Functions such that a given distribution plots as a straight line (Benjamin and Cornell, 1970).

of best fit distribution should also be based on the underlying assumptions about the model and how it may impact the end results.

Scenario 1: Prior to PR/HACCP Implementation

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

$$OM_{t(\$/lb)} = WPT_t - WCT_t, \tag{3}$$

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

$$R_t = \ln(P_t) - \ln(P_{t-1}), \tag{4}$$

where

R_t = Monthly return of turkey,
$\ln$ = Natural logarithm,
P_t = Current price of turkey, and
P_{t-1} = Previous price of turkey.

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

$$P_t^* = P_t(1 + R_{t-T}) \tag{5}$$

$$C_t^* = C_t(1 + R_{t-T}) \tag{6}$$

respectively for all T = 1…..60 or T = 61….108.

Then, the hypothetical margin was defined as

$$HM_{t-1} = P_{t-1}^* - C_{t-1}^*, \tag{7}$$

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 the BestFit™ 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 the 95% level of confidence was estimated.

Scenario 2: After PR/HACCP Implementation

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 the PR/HACCP system. The net economic benefit of the PR/HACCP system was comprised of the 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 to 2003.

To compute the net economic benefit of PR/HACCP, the risk reduction benefit of the 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 the 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 report because there was only 1 type 3 recall from 1995 to 2003.

A multinomial logit model was used 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 probit[7] or logit[8] models, the multinomial probit and multinomial logit models, respectively. These generalizations are motivated by employing the random utility model.[9]

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[7] The 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.

[8] The logit model is an alternative to the probit model in that it is linear and uses the probability density function as opposed to the cumulative distribution function as a choice of probabilities.

[9] The 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).

The three major advantages of the multinomial logit model are:

1. The advantage of this model is its computational ease,
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 3. Table 3 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*(lnL1-lnL2) 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 1 and 2 recalls are inversely related with year of PR/HACCP implementation. A 1% increase in PR/HACCP implementation would decrease Class 1 and 2 recalls by -.3912 and -.6525, respectively.

Second, the cost of recall ($/plant) was computed using the average price of wholesale turkey multiplied by the monthly volume of food recalls. However, volume of food recalls comprises only one component of the total cost of food recall; therefore, the other cost components of food recalls including transportation costs, liabilities costs, and loss of market share were computed using the top 16 turkey processors in the United States. The top 16 turkey processors in the United States account for 60% of the market share in the turkey industry. The total cost ($/plant) was computed for each month from 1995 to 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.

Table 3. 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 ($/plant) was computed for each month from 1995 to 2003. The third step was to compute the adjusted benefit ($/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 ($/lb). In this step, this was accomplished using data from the top 16 turkey processors. The adjusted benefit ($/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 to 2003. Then, the BestFit™ distribution tool was used to find the best distribution that fit the data from 1996 to 2003. This distribution provided the total risk reduction benefit from 1996 to 2003.

In order to compute the cost of PR/HACCP implementation, triangular distribution values were assumed for small, medium and large plants, which are representative of the cost function (USDA-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

$$TPM_t = WPT_t - WCT_t \pm NHB_t, \tag{8}$$

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

$$HM_{t-1} = WPT_{t-1} - WCT_{t-1} \pm NHB_{t-1}, \tag{9}$$

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. The BestFit™

distribution tool was used to find the best distribution. Then, using @Risk[Tm] software, the distribution was simulated 1,000 times and VaR at 95% confidence levels was calculated.

Scenario 3: Under More Stringent Risk Management Strategies

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 the 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 USDA-FSIS regulation are Pre-Wash (CCP5) and Visual Inspection (CCP7). The augmented CCPs in this report 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 report are:

1. Pre-Scald,
2. Post-Scald: using hot water at 150^0F,
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:

$$NB_{PR/HACCP(t)} = TR_t + VRR_t - TC_t - QL_t - IC_t - FC_t, \tag{10}$$

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 Description of Variables

Total revenue is defined as:

$$TR_t = WPT_t * NTP_t, \tag{11}$$

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

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 report, 800 data samples of *Salmonella* were used to calculate the probabilities of contamination at each CCP. Due to the relatively small number of samples 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 the 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:

$$P_c = \frac{N_a}{n}, \quad (12)$$

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 to note that 29% level of pathogen contamination at each critical limit is the required amount by the USDA-FSIS.

The value of risk of reduction is defined as:

$$VRR = (P_c * P_t * T) * \beta, \quad (13)$$

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 is defined as:

$$TC_t = C_{CCP} + C_{Labor} + CT_{Salmonella}, \qquad (14)$$

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 a difference in labor, type of *Salmonella* testing, or other costs. For example, according to statistics from the small turkey processing firm used in this report, the cost of one *Salmonella* test can range from $10 to $14. Also, the salary of an employee in charge of food safety can vary from $8 to $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 presents the distributions for the three testing cost components.

Table 4. 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 *Salmonella* testing	Normal	Mean ($12) & Stdev ($2)

The quality loss function used in this report 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 believed 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 nonconformance. Figure 1 presents the Taguchi loss function and its characteristics.

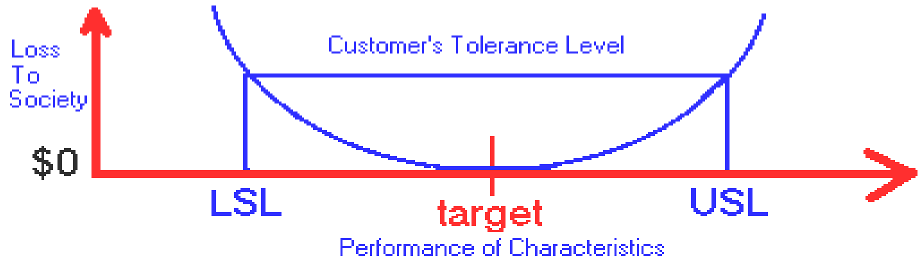

Figure 1. Taguchi loss function

The Taguchi loss function is traditionally represented as:

$$L(y) = k(y - m)^2, \qquad (15)$$

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 large-is-better. The small-is-better and large-is-better can be modeled as $L(y) = k(y)^2$ and $L(y) = 1/y^2$, respectively. However, this report examined the Taguchi loss function for sample of turkey birds with small-is-better characteristics in which the target value is zero and no negative values are assumed. The Taguchi loss function is defined as

$$L = \frac{A_0}{\Delta_0^2} * \sigma^2, \qquad (16)$$

where

$L =$ The Taguchi loss function with small-is-better characteristics,
$\Delta_0 =$ The imposed USDA upper tolerance limit,
$A_0 =$ Welfare loss to society when upper tolerance limit is exceeded, and
$\sigma^2 =$ 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:

$$A_0 = D + P_m + (R * P_t), \qquad (17)$$

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 turkeys that are not sold because of outbreak.

The welfare loss is distributed among the eight CCPs used in this report. The main objective of the Taguchi loss function in equation 16 is to minimize total costs, which include the cost of testing and the quality loss of nonconformance to a target.

The input variable cost of turkey is defined as:

$$IC_t = WCT_t * NTP_t, \tag{18}$$

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 the number of turkeys processed per day, number of working days per month, and turkey weight.
The fixed cost of the PR/HACCP plan is defined as:

$$FC_t = \frac{FCE}{BPH}, \tag{19}$$

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 the PR/HACCP plan for a plant. We assumed that the life for PR/HACCP equipment is 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 the PR/HACCP plan was computed as:

$$BPH = WPB * NDW * NTP, \tag{20}$$

where

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

WPB = Weight pound per bird,

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

NTP = Number of birds 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:

$$NB_{PR/HACCP(t-1)} = TR_{t-1} + VRR_{t-1} - TC_{t-1} - QL_{t-1} - IC_{t-1} - FC_{t-1}, \qquad (21)$$

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

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

$$\Pr(X; \delta, N) = \binom{N}{X} \delta^{x} (1 - \delta)^{N-X}, \qquad (22)$$

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

$$LR(\delta) = 2 [\ln(\delta^{*X} (1 - \delta^{*})^{N-X}) - \ln(\delta^{X} (1 - \delta)^{N-X})], \qquad (23)$$

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

In equation 23, 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's (1995) procedures of binomial probability distribution. The Z test is used as a bias test where large samples are normally distributed such that:

$$Z_c = L_{realized} - N(1 - c) / \sqrt{Nc(1-c)}, \qquad (24)$$

$L_{realized}$ is the number of observed violations of VaR at a given confidence level c (Mahoney, 1996). N (1-c) represents the number of violations 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.

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. Several tests can be used to overcome this problem. 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 theory[10] can be used to test for robustness if backtesting shows that the predicted VaRs are not robust. 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 report 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 profit or loss effects. Hinrichs and Odening (2003) stated that, historical simulation or the 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.

The 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 report.

[10] 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.

Data

Table 5 presents a summary of the model variables and data sources.

Table 5. Summary of Data Sources Used in This Report

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

Table 6 presents a summary of the three stochastic variables. In Table 6, the years, distributions, and parameters of the three stochastic variables are presented.

Table 7 provides two types of data sets used in this report: types of food recall and volume of food recall (lb). The period of this data ranged from 1995 to 2003. In this report, only Class 1 and 2 food recalls were used.

Class 3 food recalls were omitted from this report because it only occurred once during the period ranging from 1995 to 2003. The total volume of food recalls for each year was collected representing the combination of Class 1 and 2 food recalls.

The cost of implementing the medium value was estimated by Antle (2000); the PR/HACCP systems were taken from three different studies done on the cost effectiveness of implementing PR/HACCP. The smallest value was estimated by USDA-FSIS (1996); 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.

Table 6. 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: USDA-ERS (1995-2003).

Table 7. Class and Total Volume of Food Recall for Each Year

Year	Class 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: USDA-FSIS (1995-2003).

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 costs to be between $2 million and $10 million, depending on the size of the recall and product replacement (Kay, 2003).

Table 8 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 report 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 the characteristic turkey processing plant.

Table 8. Top 16 Turkey Processors in the United States

Turkey Processors	Live Weight* Processed (million lbs)
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 PoultryUSA Magazine* (2004).

Result of VaR Measures under Alternative Mitigation Strategies

The VaR and standard deviation results for three scenarios are reported in Table 9. 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% (USDA-FSIS, 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 9 shows that the VaR of the characteristic turkey processing plants prior to PR/HACCP implementation from 1995 to 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% confident 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 to 1999.

Table 9. 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/HACPP 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 the PR/HACCP system. The net economic benefit of the PR/HACCP system was computed using food recall data from 2000 to 2003 and the multinomial logit model. The result in Table 9 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 plant losses would not exceed $-0.04936 more than 5% of the time in any given month. Standard deviation reported in Table 9 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 the PR/HACCP system. The VaR for the generic and augmented PR/HACCP with 29%, 15%, and 5% TL are reported in Table 9. For example, VaR results 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 report that PR/HACCP implementations significantly reduce 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) show that, on average, characteristic turkey processing plants were losing $0.06905 per lb in any given month from 1995 to 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 to 2003. These results suggest that PR/HACCP can significantly reduce food safety risk and improve profitability. Thus, these results also validate the hypothesis. In addition, these results further strengthen the argument made by policymakers who advocated that implementing the PR/HACCP system can significantly reduce food safety risks. However, it is important to note the policymakers' conclusions on PR/HACCP implementation was based on society level benefits not on firm-level benefits. Thus, this report focuses on firm-level benefits of implementing the PR/HACCP systems.

Figure 2 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 to 1999, characteristic turkey processing plants experienced large fluctuations in net margin. After PR/HACCP implementation, characteristic turkey processing plants' net margins improved from 2000 to 2003. This improvement of the net margins in 2000 slightly decreases after January 2001. However, the decrease in net margins was stable and predictable compared to prior to PR/HACCP implementation. It is important to note that this did not have data up to 2004 data; therefore, we cannot conclude whether net margins continue to increase or decrease.

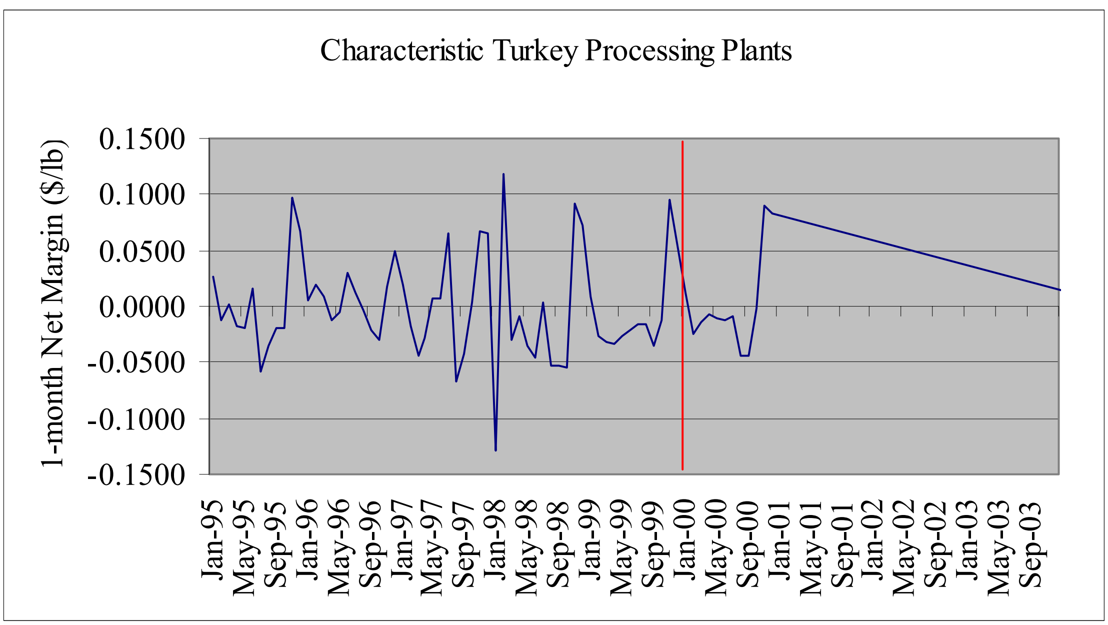

Figure 2. Monthly net margin prior to and after PR/HACCP implementation

Comparison of Scenario 3 under Case 1 and 2

Using the small turkey processing plant data, the results of the generic PR/HACCP indicate that the plant was losing $0.04916 per lb (29% TL) on average in any given month. However, the results slightly changed when the plant decided to implement the augmented PR/HACCP. The plant realized a loss of $0.04991 per lb when the augmented PR/HACCP was implemented. These results validate that the generic and augmented PR/HACCP systems reduce firm-level food safety risk and improve profitability. Figure 3 provides a graphical representation of the small turkey processing plant's monthly net margin under generic and augmented PR/HACCP with 29% TL from 2000 to 2003. This graph shows that both the generic and augmented monthly differences increase and decrease together. These results suggest that since 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 objectives/goals of the PR/HACCP system.

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 measures for all five cases are presented.

Finally, VaR estimates using RiskMetric parametric methods are discussed.

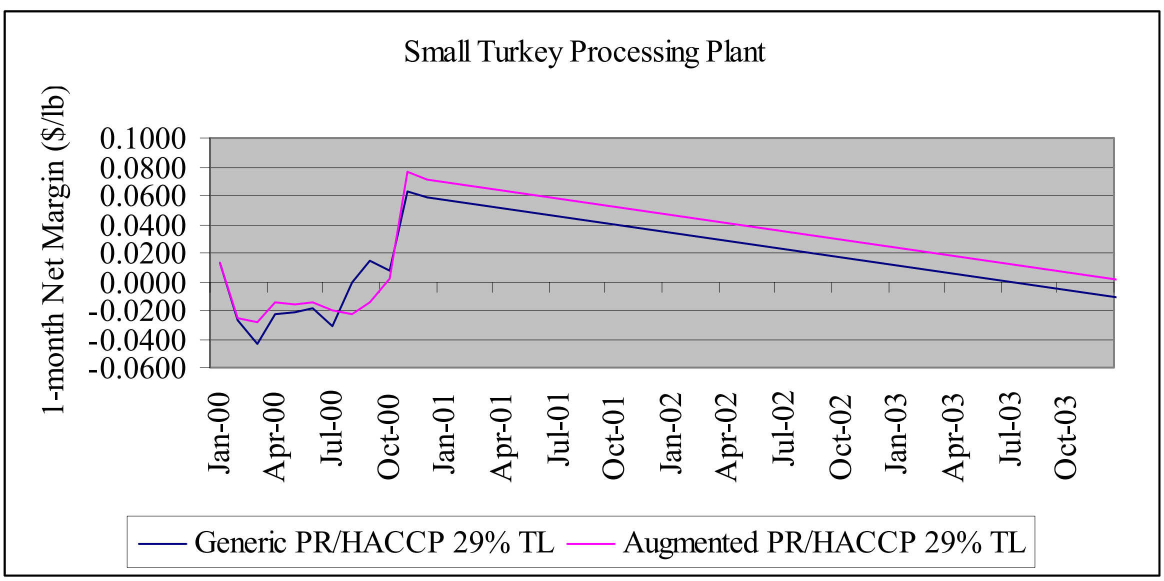

Figure 3. Comparison of monthly net margin for the small turkey processing plant: generic and augmented PR/HACCP 29% TL

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

The results of the generic and augmented PR/HACCP provided in Table 9 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 the tolerance level becomes more restricted and the level of turkey bird contamination declines, the VaR for the small turkey processing plant stabilizes. Figure 4 provides a graphical representation of the characteristic turkey processing plant's monthly differences for the generic and augmented PR/HACCP with 15% TL from 2000 to 2003. Again, this graph shows that the monthly differences of the generic and augmented PR/HACCP are moving in the same direction. Both the generic and augmented PR/HACCP systems' monthly difference increased from January 2000 to January 2001 and experienced a decrease from February 2001 to November 2003.

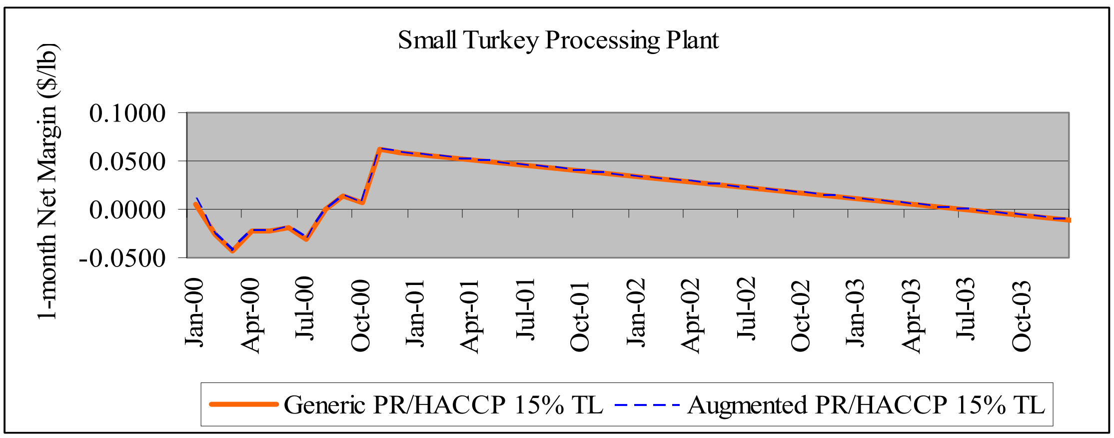

Figure 4. Comparison of monthly net margin for the small turkey processing plant: generic and augmented PR/HACCP 15% TL

__Generic and Augmented PR/HACCP with 5% TL__

The results of the generic and augmented PR/HACCP systems with 5% TL are reported in Table 9. 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 objectives/goals of the PR/HACCP system.

Figure 5 provides a graphical representation of the small turkey processing plant's monthly generic and augmented PR/HACCP systems with 5% TL from 2000 to 2003. This graph indicates that both the generic and augmented monthly difference is moving in the same direction and that there is only slight difference between the systems. To identify whether the VaR results in Table 9 are significantly different, a two-sample t-test was conducted (Table 10).

The Results in Table 10 suggest that the VaR prior to and after PR/HACCP are significantly different α=0.05. The null hypothesis is rejected. However, the VaR results of the generic and augmented PR/HACCP systems with 29%, 15%, and 5% TL suggest that VaR results are not significantly different, α=0.05.

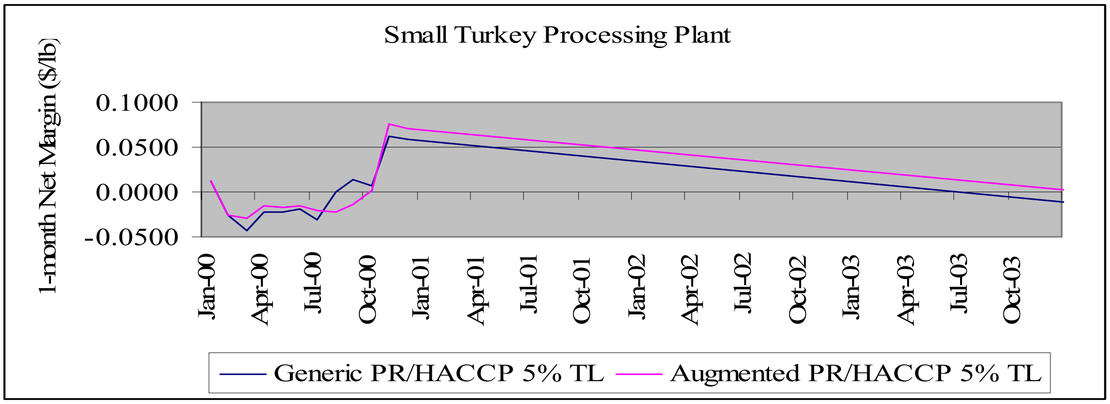

Figure 5. Comparison of monthly net margin for the small turkey processing plant: generic and augmented PR/HACCP 5% TL

Table 10. 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.

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

The results of generic PR/HACCP with 29%, 15%, and 5% TL suggests that with more restricted tolerance levels, the small turkey processing plant's monthly differences do not change. In all three cases, the monthly difference increases sharply around January 2001 and decreases gradually from April 2001 to November 2003. Figure 6 provides a graphical comparison of the small turkey processing plant's monthly generic 29%, 15%, and 5% TL from 2000 to 2003.

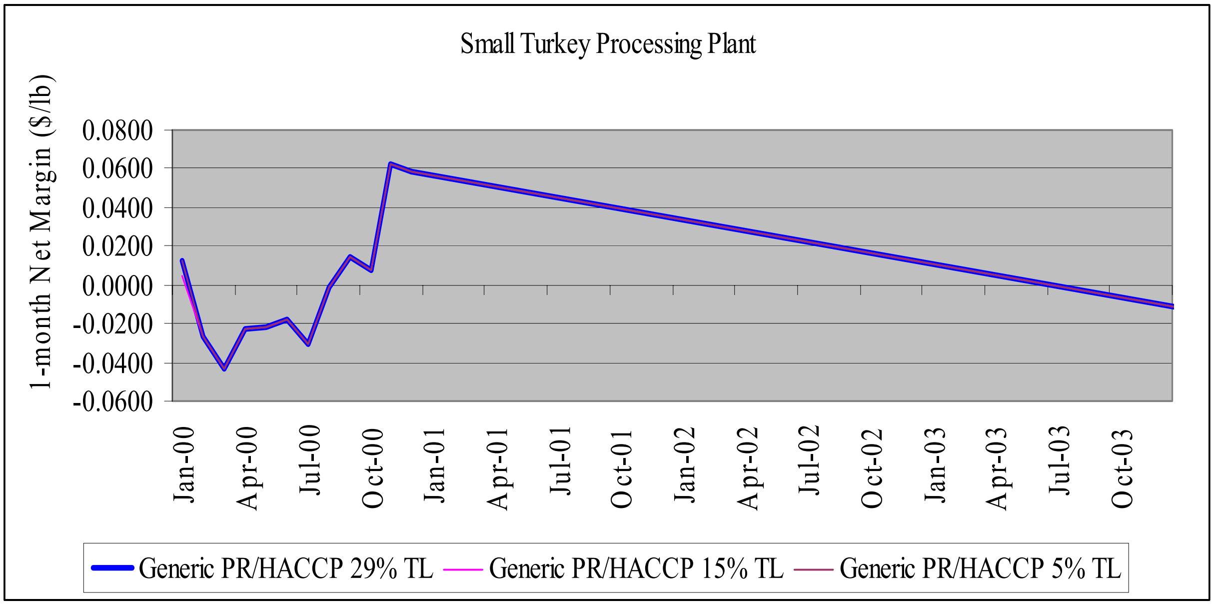

Figure 6. Comparison of monthly net margin for the small turkey processing plant: generic 29%, 15%, and 5% TL

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

These results suggest that as the tolerance levels become more restricted for the augmented PR/HACCP, they produce similar results. Thus, the benefit for the small turkey processing plant from implementing the augmented PR/HACCP increases. This concept can be validated in Figure 7. Figure 7 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 to 2003, but its monthly differences are less than the augmented PR/HACCP with 29% and 5% TL.

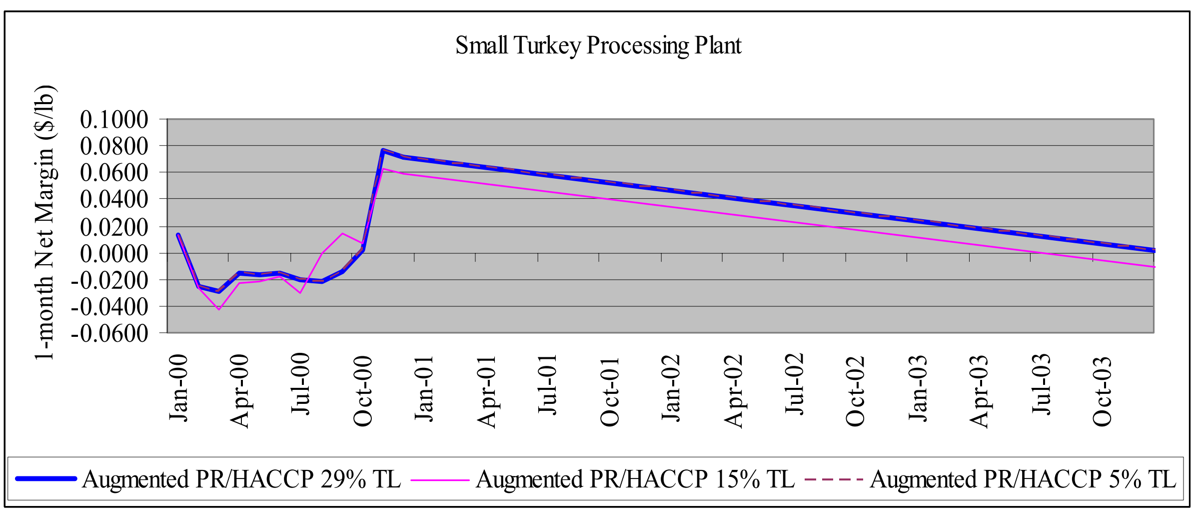

Figure 7. Comparison of monthly net margin for the small turkey processing plant: augmented 29%, 15%, and 5% TL

VaR Results with Loglogistic vs. ExtValue Distributions

In this section, the comparison of these results is made both in monthly VaR $/lb and $. These distributions are used to compare the VaR results under normal and abnormal market conditions. The results suggest that the VaR under normal and abnormal market conditions are not significantly different. For example, Table 11 reports that, in scenario 1, the monthly VaR ($) 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 in Table 11. Under both distributions, the results are not significantly 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.

Table 11. 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/HACPP 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

Finally, Table 12 reports parametric (RiskMetrics) VaR results at λ=.97 and λ=.94 decay factors. These results indicate that prior to PR/HACCP implementation, small turkey processing plants were losing $ -4,783 (λ=.97) and $-5,294 (λ=.94). However, after PR/HACCP implementation, small turkey processing plants experienced large decreases in their VaR of $-1,965 (λ=.97) and $-1,812 (λ=.94). These results further validate the hypothesis that implementing the PR/HACCP system can significantly reduce food safety risk and improve profitability. Both parametric (RiskMetrics) and full-valuation (historical simulation) methods suggest that implementing PR/HACCP can reduce food safety risk and improve profitability for the small turkey processing plants.

Table 12. Parametric (RiskMetrics) Method Results

Scenario	Description	Monthly VaR($/lb), λ=.97	Monthly VaR($), λ=.97	Monthly VaR($/lb), λ=.94	Monthly VaR($), λ=.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

Results of Out-of-Sample Testing

Table 13 presents the out-of-sample test results for the three scenarios with 95% confidence level. The out-of-sample analysis was conducted using likelihood ratio and Z tests. Scenario 3 was divided into generic and augmented PR/HACCP with 29%, 15%, and 5% TL.

The results in Table 13 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 the 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 failed to reject the null hypothesis that the number of violations realized over the period equals the number 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 13 also reports the out-of-sample test results for scenarios 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 13. 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

Table 14 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 14 indicate that both the LR statistic of 0.238 (6.635) and Z statistic 0.536 (2.576) are not significance 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 failed 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 14 also presents results of scenarios 2 and 3 for the LR statistic and Z test. In both cases, the results suggest that the LR and Z statistics are not significant at the 1% level.

Table 14. 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/HACPP 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

Management Implications and Discussion

This report focused on the turkey industry. In 2003, turkey as a food commodity amounted to $2.72 billion in U.S. 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 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 report 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 systems 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, policymakers must verify the benefit of regulatory requirements before implementing a system like PR/HACCP. The USDA-FSIS (1996) stated that regulating food safety with PR/HACCP programs constitutes a major rule under both the Executive Orders[11] and the Regulatory Flexibility Act.[12] For example, FSIS cost-benefit analysis of mandatory PR/HACCP implementation was based on the effect at the level of society. However, the results of this report can provide policymakers with firm-level benefits of implementing the PR/HACCP system; thus, justifying its significance to the reduction of the overall food safety risks.

Summary and Limitations

The purpose of this report was to determine the risk reduction capabilities and performances of the PR/HACCP systems. More specifically, the **three** objectives of this report were to determine the risk (firm-level economic loss) reducing impacts of PR/HACCP using VaR; to evaluate the effectiveness of VaR in predicting food safety losses incurred by the characteristic and small turkey processing plants under three

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[11] Executive Orders or acts protect businesses against costly regulatory procedures. It also compels agencies to use cost-benefit analysis as a component of decision making.

[12] The Regulatory Flexibility Act requires regulatory relief for small businesses where feasible.

alternative scenarios. The likelihood ratio and Z tests were used to evaluate the effectiveness or robustness of VaR estimates, and to help both firm managers and policymakers to better understand the use of VaR as a risk measurement and management tool for food safety risk.

The results of this analysis indicated that VaR was adequate in predicting food safety losses attributed to food recalls by the characteristic turkey processing plant prior to and after PR/HACCP implementation. Also, VaR was adequate in predicting food safety losses attributed to actual microbial count by the small turkey processing plant. Finally, these results validate the hypothesis that PR/HACCP implementation significantly reduces firm-level food safety risk and improves profitability.

Firms that exited the industry during the PR/HACCP implementation were not incorporated in the analysis due to difficulties in accessing data for these firms. PR/HACCP has improved the performance of the industry. Firms not operating efficiently may be forced to exit the industry. Further studies in the aggregate impact of all firms including these that have exited might be plausible. Another limitation of this report is that not all the benefits of PR/HACCP, like increased shelf life and access to new markets, especially international markets, can be captured directly with VaR. Finally, this report did not address the level of acceptable VaR. The level of acceptable VaR would depend on the plant's objectives and degree of risk aversion.

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