



Using VaR to Predict Food Safety Losses in Meat and Poultry Processing

William E. Nganje
North Dakota State University
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Outline

- **Introduction**
 - Food Safety Risks and Risk Mitigation Alternatives
 - Observations and Challenges
 - Objectives and Hypothesis
- **Value at Risk Methods and Procedures**
 - **For a characteristic processing firm**
 - Prior to, during, and after PR/HACCP implementation
 - For generic versus augmented PR/HACCP systems
 - **For a retail firm**
 - With SOP and random USDA checks
 - With SOP, contracts and random USDA checks
 - With voluntary PR/HACCP systems
- **Results**
 - VaR for turkey processing prior to, during, and after PR/HACCP
 - VaR for alternative mitigation strategies at retail
 - Robustness of results
- **Conclusion and Management Implications**



Food Safety Risks and Risk Mitigation Alternatives

□ **Foods Safety Risks**

➤ **Sickness and deaths**

- An estimated 76 million foodborne illnesses occur each year in the United States (CDC)
- Of these cases, 325,000 are hospitalized and 5000 deaths occur each year (Mead et al., 1999).
- Economic costs to society range between \$6.5 billion and \$13.3 billion a year. (see Crutchfield and Roberts, 2000; Buzby, Frenzen and Rasco, 2001).

➤ **Food Recalls and Firm-level economic losses**

- NFSIS records of food recalls from 1994-2003 estimated \$1.35 billion loss in the turkey industry alone.

□ **Risk Mitigation Strategies**

- Mandatory PR/HACCP for processing and packaging
- Retail has varying strategies based on cost-risk
 - With SOP and random USDA checks
 - With SOP, contracts and random USDA checks
 - Voluntary PR/HACCP



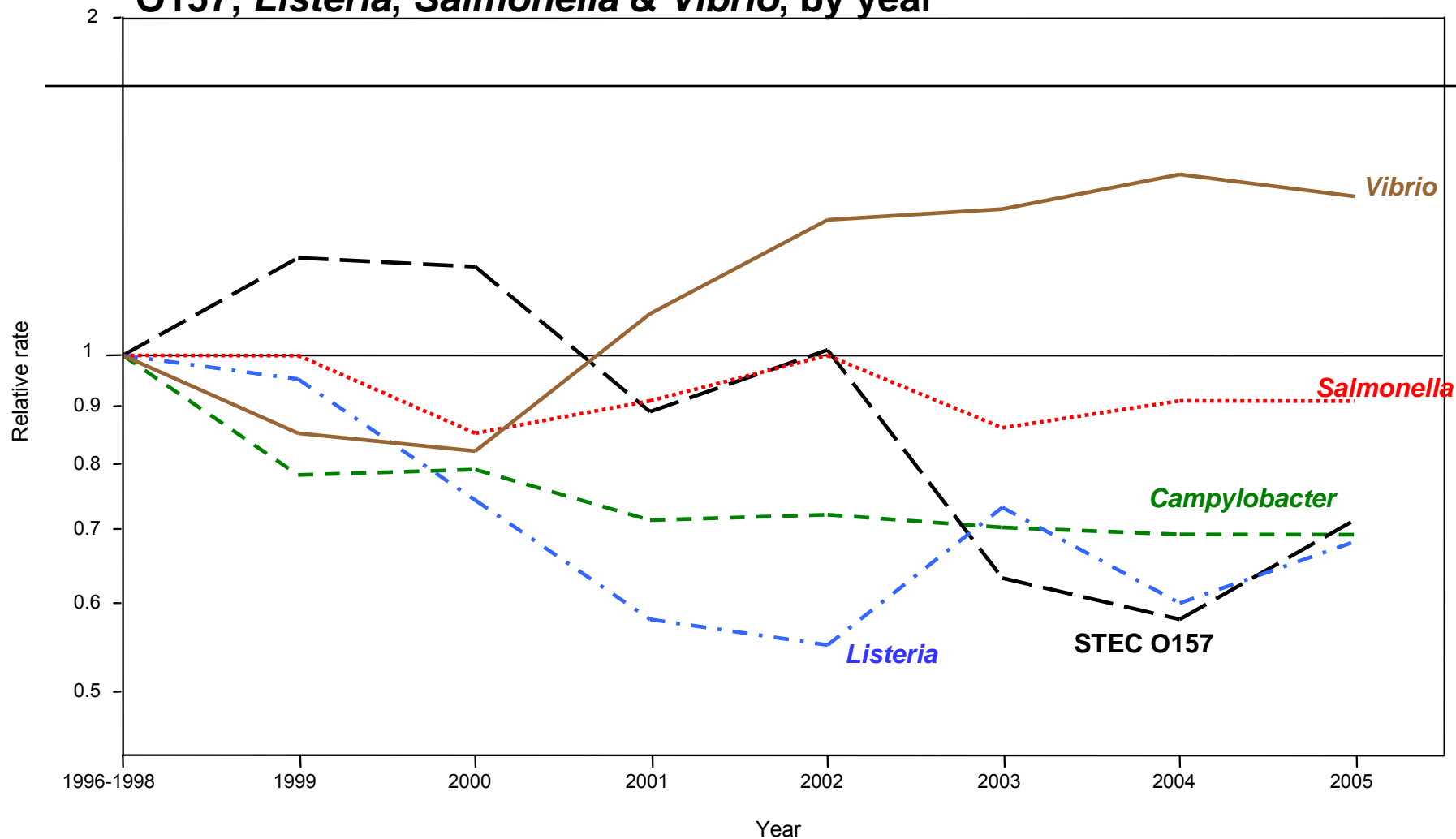
Observations

Trends: 2005 FoodNet Data

↓ 30% Campylobacter	↓ 32% Listeria
↓ 9% Salmonella	↓ 43% Shigella
↓ 29% E. coli O157	↑ 41% <i>Vibrio</i>
↓ 49% Yersinia	

"Preliminary FoodNet Data on the Incidence of Foodborne Illnesses -- Selected Sites, United States, 2005" Morbidity & Mortality Weekly Report (April 14, 2006) <http://www.cdc.gov/mmwr/>.

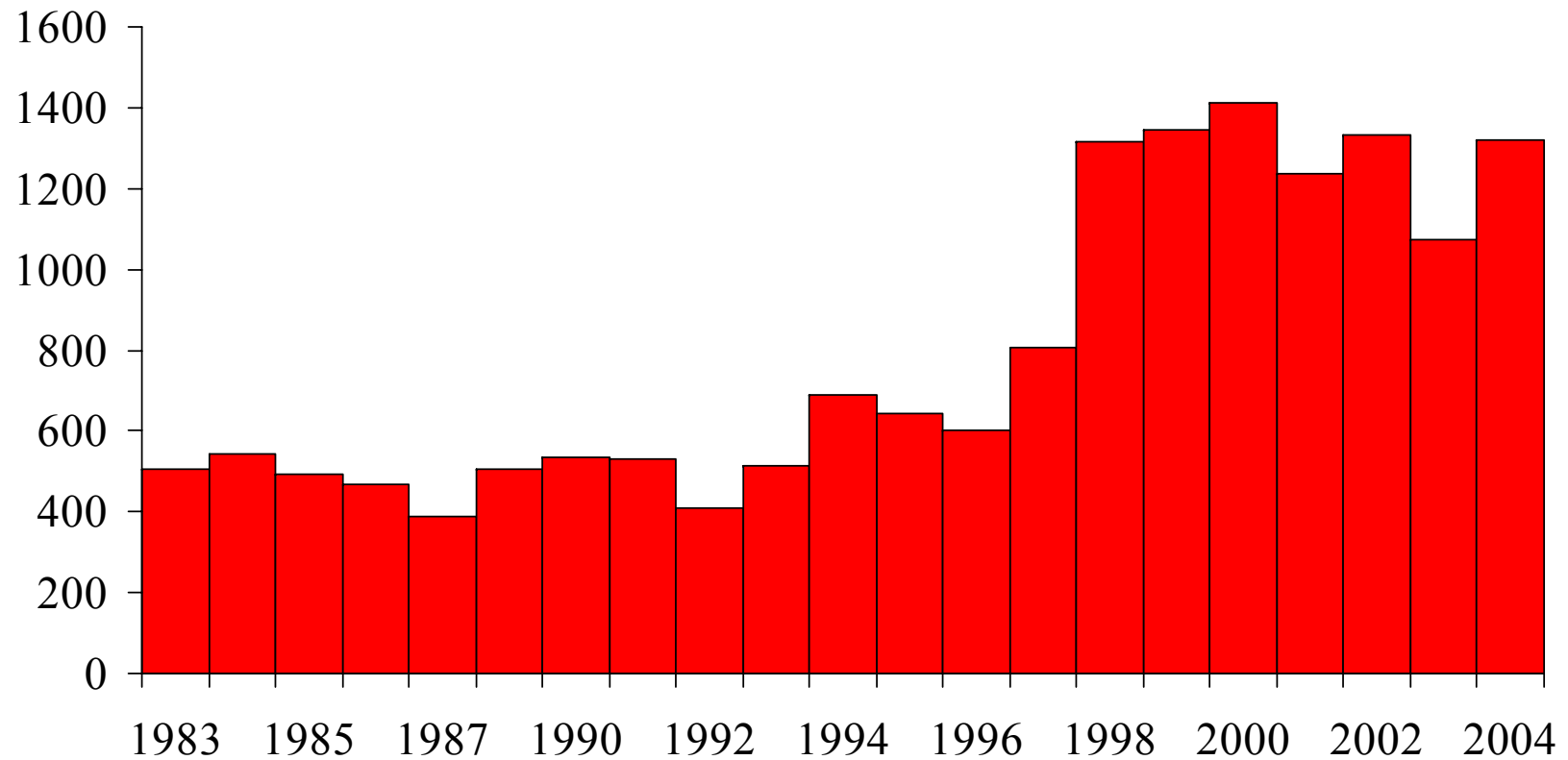
Trends: Relative rates compared with 1996–1998 baseline period of laboratory-diagnosed cases of infection with *Campylobacter*, STEC O157, *Listeria*, *Salmonella* & *Vibrio*, by year



Challenges

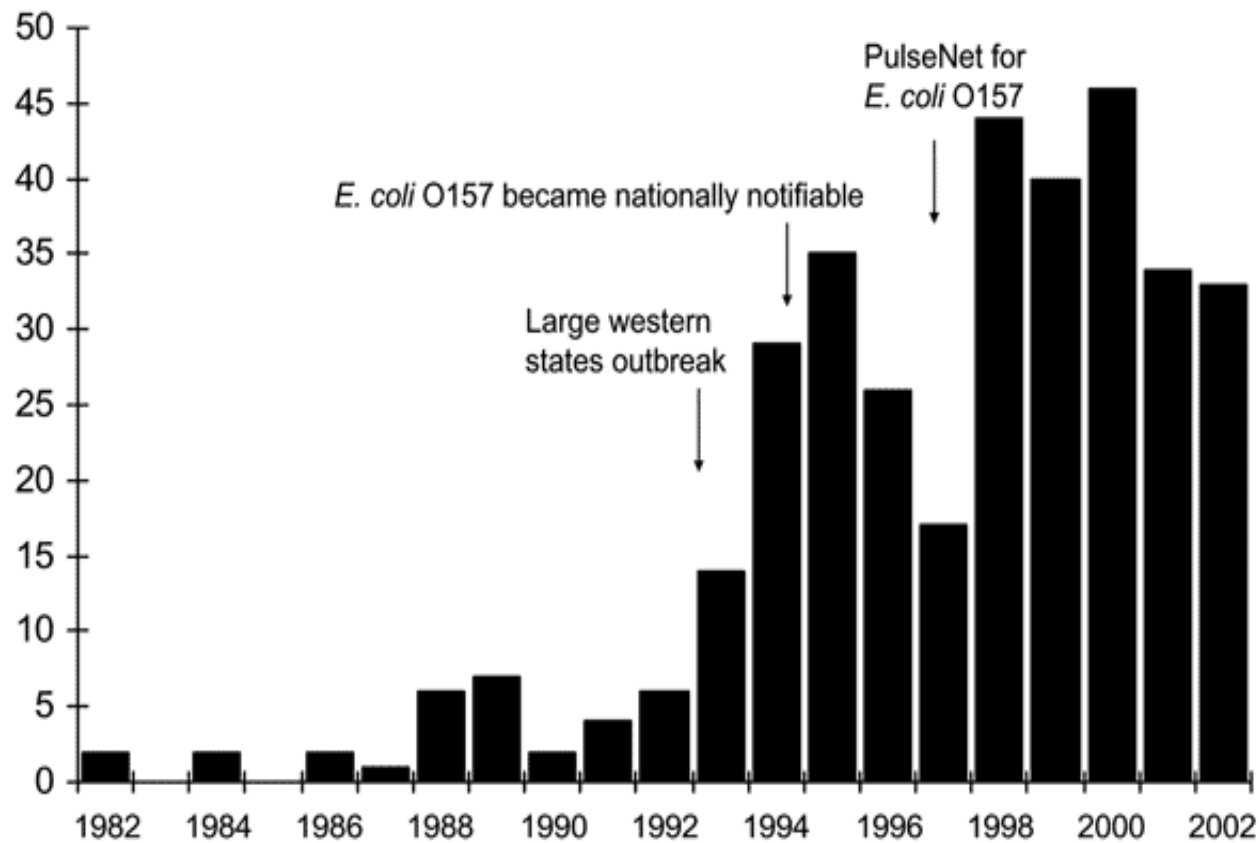
Trends: Foodborne Disease Outbreak Surveillance System

of outbreaks



* CDC preliminary data

Trends: Reported outbreaks of *E. coli* O157:H7 infections in the United States 1982-2002



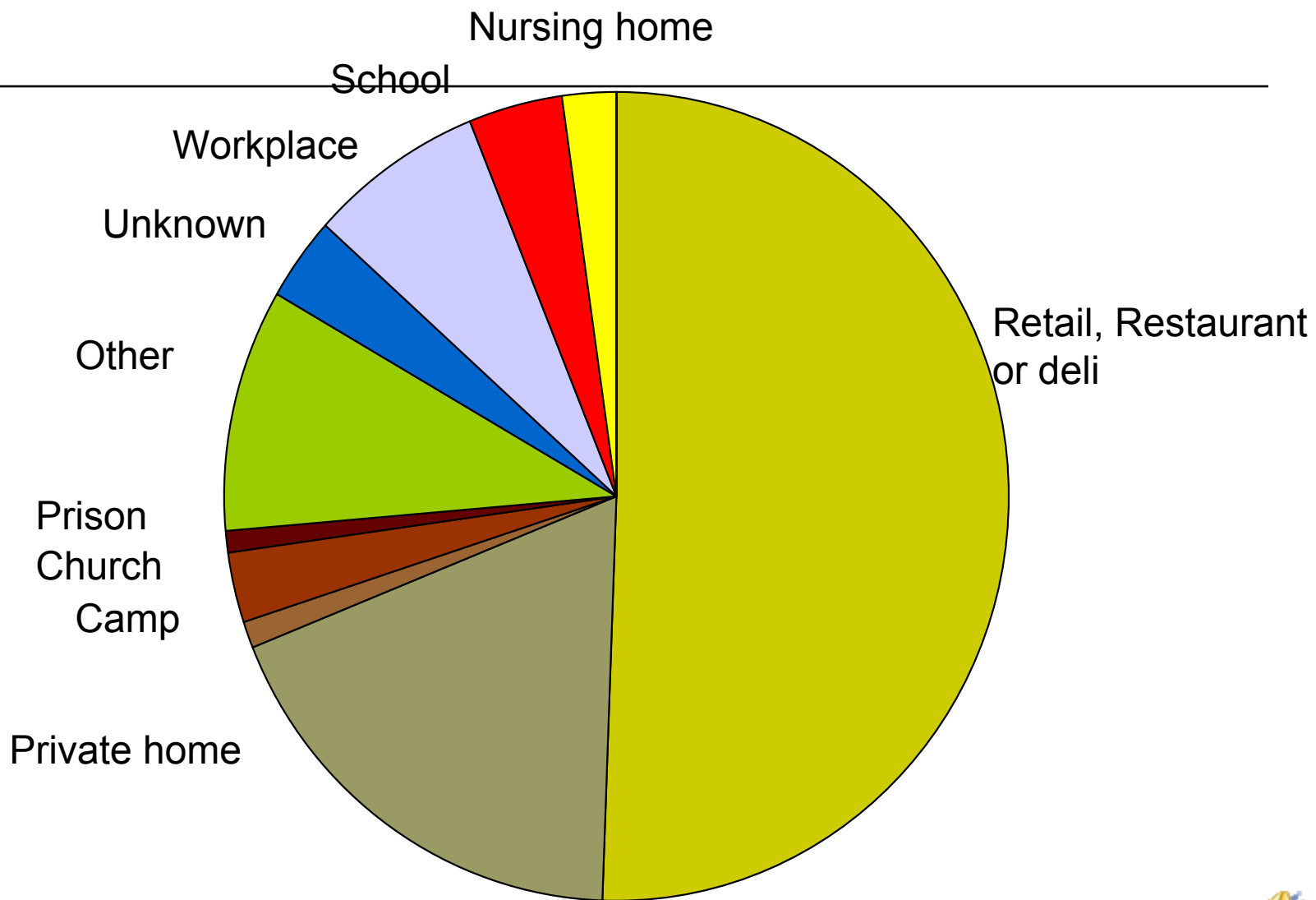
Rangel et al, EID 11:603-609, 2005



Yearly Aggregated Beef Recalls (lbs) from 1995-2005

Year	Class 1 Recall	Class 2 Recall	Class 3 Recall
1995	1,123,726	32,674	0
1996	173,114	39,420	0
1997	26,913,978	711,515	0
1998	39,761,130	179,188	1,343
1999	3,433,043	27,560	0
2000	2,514,946	429,536	0
2001	2,194,285	491,000	1,628,600
2002	24,328,861	115,700	142,600
2003	1,239,646	195,100	471,779
2004	1,403,310	340,540	255,210
2005	1,740,230	0	0

Location of Foodborne Disease Outbreaks, 2004 (N=1319)



* Very Preliminary data





Objectives and Hypothesis

- The goal of this study are two folds: 1) predict firm-level food safety losses under alternative mitigation strategies for processing and retail and 2) determine the value of risk reduction of PR/HACCP systems.
- The testable hypothesis in this study is that PR/HACCP implementation significantly reduces pathogen prevalence/recalls and improves firm-level profitability.



Value at Risk Methods

- VaR is the probability of a portfolio of assets losing a certain amount in a given period at a particular level of confidence.
 - Full Valuation methods: Historical Simulation and Monte Carlo Simulation (Nganje, Kaitibie, Saipay and Acquah 2006; Manfredo and Leuthold, 2001; Linsmeier and Pearson 1996; Mahoney, 1995).
 - Parametric valuation methods (Nganje, Kaitibie, Saipay and Acquah 2006; Manfredo and Leuthold, 2001).
- Advantages of VaR
 - VaR gives managers the ability to think of risk in monetary terms instead of risk as variability or standard deviation.
 - Upper managers may find VaR easy to estimate and interpret results.
 - VaR focuses on the downside risk.
 - VaR measures portfolio risk, including intangible incentives.



Historic Simulation Procedure Using Recall Data

$$\text{TPM}_t = \text{WPT}_t - \text{WCT}_t \pm \text{NHB}_t \quad (15)$$

Where:

TPM_t = Net margin in current period,

WPT_t = Unit return in current period,

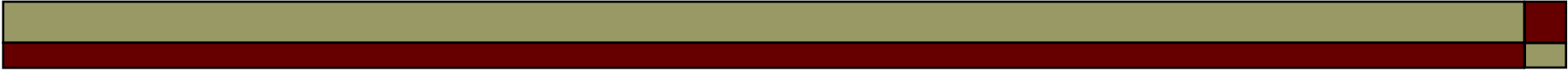
WCT_t = Unit cost in current period,

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

Estimating the Marginal Impact or Elasticities of Probabilities Of PR/HACCP Using Multinomial Logit Model

Dependent Variable*	Independent Variable	Coefficient	Standard Error	P[Z] > z	Elasticities of Probabilities
Class of Recall = Class 1	HACCP Period I	-2.3026	1.0488	0.0281	-0.2132
	HACCP Period II	-2.1282	0.4731	0.0000	-0.8127
	HACCP Period III	-1.3291	0.3749	0.0004	-0.3912
Class of Recall = Class 2	HACCP Period I	-2.3026	1.0488	0.0281	-0.2132
	HACCP Period II	-3.7377	1.0118	0.0002	0.0000
	HACCP Period III	-1.9169	0.4790	0.0001	-0.6525

*Note that “Class of Recall = no recall” is the base case.



Stochastic Simulation Procedure with Microbial Data from PR/HACCP and Retail Strategies

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

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,

FC_t = Total Fixed Cost per month in current period.

Stochastic Optimization Model

- Model is developed to maximize the utility of net benefits
 - Uses expo-power utility function (Saha)
 - Von-Neumann-Morgenstern utility with decreasing absolute risk aversion and increasing relative risk aversion

$$\underset{\beta, n}{\text{Maximize}} E[U(NB)] = E(\lambda - e^{-\alpha NB(\beta, n)^\delta}),$$

where α and δ are parameters that affect absolute and relative risk aversion of the utility function, $\alpha \neq 0$, $\delta \neq 0$, $\alpha\delta > 0$;

λ is a parameter that determines the positiveness of the utility function



Generic versus Augmented PR/HACCP

- Eight potential CCPs used 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
 8. Chill: Temperature control.

Optimal Strategies for *Salmonella* Testing and HACCP Implementation under Decreasing Absolute Risk Aversion and Increasing Relative Risk Aversion ($\alpha=0.00005$, $\delta=0.04$) for Processors

Critical Control Point	29 % Tolerance		15% Tolerance		5% Tolerance	
	Test Decision	# of Samples	Test Decision	# of Samples	Test Decision	# of Samples
Pre-scald			Test	2	Test	2
Post-scald	Test	2	Test	2	Test	2
Pre-evisceration	Test	2	Test	2	Test	2
Pre-wash	Test	2	Test	2	Test	2
Post-wash					Test	2
Post-evisceration					Test	2
Visual Inspection	Test	2	Test	2	Test	2
Chill	Test	2	Test	2	Test	2
Net Benefit		146,940		109,311		(830,334)

Test for Robustness

□ **Backtesting 1**

- Following Manfredo and Leuthold (2001) and Lopez (1997), the likelihood ratio test statistic for out-of-sample testing is defined as

- $LR(\alpha) = 2 [\ln(\alpha^X (1-\alpha)^{N-X}) - \ln(\alpha^X (1-\alpha)^{N-X})]$.

- The null hypothesis is that $\alpha = \alpha^*$, where α^* is the desired coverage level (5%) corresponding to the 95% level of confidence, and α^* is defined as X/N (where X is the number of out-of-sample violations and N is the number of out-of-sample observations). If we fail to reject the null hypothesis, then actual food safety losses did not exceed those predicted by the VaR model.

□ **Backtesting 2**

- Following Mahoney (1995), the Z test is used as bias test where large samples are normally distributed such that

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

- where $L_{realized}$ is the number of observed violations of VaR at a given confidence level c , $N(1-c)$ represents the number of violation of VaR estimations, and N is the number of out-of-sample observations. When the Z test is significantly positive (or negative), then VaR underestimates (or overestimates) the actual downside risks.



Summary of Data and Data Sources for Historic Simulation

Model Variables	Data Sources
Wholesale prices of Beef (1995-2005)	Livestock, Dairy, and Poultry outlook, Economic Research Service.
Wholesale cost of beef (1995-2005)	Livestock, Dairy, and Poultry outlook, Economic Research Service.
Type of food recall and volume of food recall (1995-2005)	Food Safety and Inspection Service.
Cost of PR/HACCP System	Boland et al. (2001); Federal Register; and Antle (2000).
Total product of volume recall	Food Safety and Inspection Services.
Volume of beef processed	Livestock, Dairy, and Poultry outlook, Economic Research Service.



Data for Stochastic Simulation Procedure

- Total testing cost components include fixed costs of \$37 at critical control point
- Labor costs (following a normal distribution with mean \$14 and standard deviation of \$6)
- *Salmonella* testing fees (following a normal distribution with mean \$12, and standard deviation of \$2).
- Taguchi quality loss function for smaller is better is used in conjuncture with *Salmonella* contamination probabilities to calculated losses due to microbial pathogen (*Salmonella*) at *alternative* tolerance levels 29%, 15%, and 5%.
 - It is important to note that 29% level of *Salmonella* contamination at each critical limit is the required performance standard by the FSIS for ground turkey.



Data for Stochastic Simulation Procedure

Top Processors of Turkey-Beef-Pork-Chicken

Name of Top Firms	Volume (Millions of lbs)	Volume of Shipment (%)
Turkey Cargill Turkey Products, Jennie-O Turkey Store, Butterball Turkey Co, Carolina Turkeys, Pilgrims Pride, Louis Rich Turkey Co, Sara Lee Refrigerated Foods, House of Raeford, Perdue Farms, Inc., Foster Farms IBP, Inc (Tyson), Excel Corporation (Cargill), ConAgra Beef Cie, Farmland National Beef Packing Corp,	5,576	80.2
Beef Smithfield Foods Inc, Rosen's Divesified, Inc, Greater Omaha Packing Co Inc, Nebraska Beef Inc, American Foods Grp, Beef Packers, Inc Smithfield Foods Inc, IBP, Inc (Tyson), Swift & Co (ConAgra Foods Inc), Excel Corp (Cargill, Inc), Hormel	18,051	74.3
Pork Foods Corp, Farmland Foods, Premium Standard Farms(Conti Group), Seaboard Corp, Indiana Packers, Iowa Packing Corp Tyson Foods Inc, Gold Kist Inc, Pilgrim's Pride corp, ConAgra Poultry Corp, Perdue Farms Inc, Wayne	15,327	85.1
Chicken Farms (ContiGroup), Sanderson Farms Inc, Cagle's Inc, Foster Farms, Mountaire Farms Inc	20,926	74.0

Results

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

Scenario	Description	Average VaR (\$/lb)	Standard Deviation
Scenario I	Prior to PR/HACCP implementation (1995-1999)	-0.06905	0.04499
Scenario II	After PR/HACCP implementation (2000-2003)	-0.04936	0.03175
Scenario III	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

Robustness Results

Table 5.2: Out-of- Sample Test for the 95% Confidence Level

Scenario	Description	LR Statistic	Z Statistic
Scenario I	Prior to PR/HACCP implementation (1995-1999)	1.803	-1.165
Scenario II	After PR/HACCP implementation (2000-2003)	0.058	-0.234
Scenario III	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

*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.



Summary of VaR and Standard Deviation for Beef Retail

Scenario	Description	Average VaR (\$/lb)	Standard Deviation
Scenario I	Prior to PR/HACCP Implementation (1970-1995)	-0.09323	0.05342
	During HACCP Implementation (1996-1999)	-0.09701	0.05962
Scenario II	After PR/HACCP Implementation (2000-2005)	-0.2111	0.12718

Sensitivity of Results

(VaR with Normal and Logistic and ExtValue Distributions (Monthly Volume Processed= 13721.72011 lbs))

Scenario	Description	Monthly VaR(\$/lb) Normal Dist	Monthly VaR(\$) Normal Dist	Monthly VaR(\$/lb) Logistic Dist	Monthly VaR(\$) Logistic Dist	Monthly VaR(\$/lb) ExtValue Dist	Monthly VaR(\$) ExtValue Dist
Strategy 1	SOP, Contracts, & USDA	-0.09380	-1279.276	-0.09323	-1279.276	-0.09424	-1293.135
Strategy 2	Voluntary PR/HACCP	-0.09701	-1331.144	-0.09409	-1291.077	-0.09975	-1368.742
Strategy 3	SOP and USDA	-0.2181	-2896.655	-0.2111	-2896.655	-0.2482	-3405.731

Robustness of Results

(Out-of Sample Test for the 95% Confidence Level)

Scenario	Description	LR Statistic	Z Statistic
Strategy 1	SOP, Contracts, & USDA	0.1287	0.3637
Strategy 2	PR/HACCP	0.0742	-0.2649
Strategy 3	SOP & USDA	0.8860	-0.8652
Alternative Tolerance	29% Tolerance	0.11132	-0.3244
	15% Tolerance	0.11132	-0.3244
	10% Tolerance	0.11132	-0.3244
	5% Tolerance	0.11132	-0.3244
	1% Tolerance	0.11132	-0.3244



Conclusion

- VaR was adequate in predicting food safety losses due to food recalls prior to and after PR/HACCP implementation.
- VaR was adequate in predicting food safety losses with pathogen prevalence data.
- The results validate the hypothesis that PR/HACCP implementation significantly reduces firm-level food safety risk and improves profitability.
- Moves to implement PR/HACCP all along the supply chain should be encouraged.



Management Implications

- VaR methods and results can assist management to quantify their respective benefit of PR/HACCP and provide guidance for augmented HACCP systems.
 - The results indicate that losses incurred by a processing firm under generic and augmented PR/HACCP are not significantly different.

“If we knew what we were doing, it wouldn’t be called research, would it?”

