CHOICES
The magazine of food, farm, and resource issues
2nd Quarter 2005 • 20(2)
A publication of the American Agricultural Economics Association

# Economics of Private Strategies to Control Foodborne Pathogens

By Tanya Roberts

Foodborne pathogens are naturally occurring contaminants that public policies and private strategies target for control. In the 1990s, both the Food and Drug Administration (FDA; US Department of Health and Human Services) and the Food Safety and Inspection Service (FSIS; Department of Agriculture) required a new system for many regulated food plants. Hazard Analysis and Critical Control Points (HACCP) is based on preventing pathogens from entering the food supply chain and controlling this contamination after it occurs. The new federal HACCP regulations have not automatically solved the pathogen-contamination problem, and foodborne illness outbreaks and product recalls continue.

This paper examines the role of public and private economic incentives in the market for food safety, how pathogen information influences this market, the variety of strategies firms use to control foodborne pathogens, and the firm's package of choices: Are inputs sold for a cooked or raw product? What are the safety requirements of buyers? What is the risk a firm is willing to bear of a foodborne disease outbreak or product recall? In evaluating economic incentives for pathogen control, the food safety externalities caused by joint production of quality attributes are often overlooked but may alter the willingness of a firm to adopt food safety controls. This paper focuses on the supply chain for meat and poultry products, estimated to cause more than 40% of human illnesses associated with common pathogens. Case studies are examined for economic incentives for achieving pathogen control.

## Role of Information in Economic Models

Although neoclassical economics assumed zero information and transaction costs, Akerlof's seminal article on the used car market (1970) created awareness of how missing information about quality alters the marketplace. In today's knowledge economy, the role of information has become even more central (Metcalf, 1995). Firms do not have equal access to information; this asymmetry is a driving force in the economic selection process, in how different technologies change over time, and in core policy-making behavior within a firm that can hinder or enhance the creative process. Competition is a process of change in an inefficient world. On the empirical front, Metcalf reports that firms in the United Kingdom's manufacturing industries have "substantial unit cost deviations from best practice" (p. 472), even in very competitive environments. As evolutionary economists predicted, the range of firm efficiencies was most diverse in rapidly growing industries. New shocks, such as changes in demand and development of new technologies, add to the inefficiency of old behaviors in the framework of evolutionary economics and give firms new opportunities for creating profit.

## HACCP Regulations and New Tests Shock Food Safety Markets

Firms used to talk of testing for pathogens as looking for a needle in a haystack—lingo that is no longer heard. Improved tests and pathogen surveillance systems have undergone a sea change in the past decade (Unnevehr, Roberts, & Custer, 2004). The problem of false positives caused by DNA from killed pathogens has been solved. Tests are faster, cheaper, and much more highly automated with standardized results. Most significantly, new information revealed by better pathogen tests allows firms to develop new control strategies, because the tests are reliable enough to document the impact of alternative control strategies on pathogens. Both the public and private sectors are reacting around the globe, tightening pathogen control with new regulations or contract provisions.

To comply with the FSIS HACCP regulations, meat and poultry plants have to follow standard sanitation oper-

ating procedures, test for generic *E. coli*, and develop a seven-point HACCP plan to monitor and control production operations: (a) identify food safety hazards; (b) identify critical control points (CCP); (c) set critical limits for each CCP; (d) develop CCP monitoring procedures; (e) perform corrective actions; (f) establish recordkeeping systems; and (g) verify the system is working as planned. Under the HACCP regulations, FSIS tests for *Salmonella* on raw meat and poultry products. If the plant fails *Salmonella* tests, their HACCP plan is subject to an in-depth review by FSIS.

## Joint Production Functions Reduce Costs

One factor complicating economic analysis is the joint production function between pathogen control and other economic benefits. McDonald's clamshell cookers were put into use in 1984 to meet three objectives: to cook patties faster, to reduce labor costs, and to enhance food safety. More uniform cooking was achieved by simultaneously heating the patty from both sides in the clamshell cooker. Cost savings and pathogen control were complementary objectives for McDonald's. The American Meat Institute reports that companies find shelf-life extension to be a benefit from pathogen control in combination with new packaging systems. Economic analyses of the marginal costs of pathogen control, then, are more complete if they include estimates of the savings derived from these joint-production-function benefits.

Mazzocco (1996) reports that the business management literature on quality control and innovation reveals that "the cost of poor quality exceeds the cost of developing processes which produce high-quality products" (p. 770). The characteristics of internally driven quality management systems include heavy reliance on employee involvement, development of new measurement methods (e.g., new pathogen tests), and continual change in processes. The private application of process control complements FDA and FSIS HACCP regulations to control pathogens in the food supply chain.

## Firm Strategies for Pathogen Control

Traditional methods of pathogen control in foods include drying, curing, salting, sugaring, heating, and cooling. A "kill step," such as pasteurizing food in cans or cooking meat well-done just before serving, can effectively control pathogens. A kill step, however, can create quality tradeoffs, such as changes in flavor and texture (Ralston, Brent, Starke, Riggins, & Lin, 2002). The food industry typically designs new food products with multiple hurdles that either kill pathogens or minimize pathogen growth. Some meat and poultry producers now use multiple hurdles to control pathogens in their production processes for raw products. Other firms, however, may choose to ignore pathogen contamination of the foods they produce. These firms are then faced with an increased risk of legal liability when consumers become ill, when the CDC reports an outbreak associated with their product, or when the FSIS requests a recall of product that has failed a pathogen test. Ollinger and Ballenger (2003) report that badly managed meat and poultry plants tend to go out of business.

A firm's choice of a pathogen control strategy is influenced by how strictly it chooses to control pathogens in specific raw meat products. Within a meat company, the target level for pathogen control can vary by plant and/or product. For example, plants slaughtering bulls and cows used in breeding and milk production sell in three markets with differing levels of pathogen risk in their final marketplace products: high-risk raw ground beef market (grinding mixes pathogens throughout), medium-risk roast market (pathogens remain on the exterior and are killed by conventional cooking), and low-risk processed products, such as soup that is cooked thoroughly. Different requirements for pathogen control exist in each of these three markets. Different requirements also exist in the international marketplace. A firm must analyze its competitive advantage: Is it competing today on low price, high safety, or high quality (tenderness or a product sold in the organic market)?. What is the firm competing on tomorrow in this dynamic environment of improving food safety knowledge?

Based on implementation of HACCP, industry literature, and risk assessment models, meat and poultry firms use seven generic strategies to control pathogens in their products. Combinations of the strategies are often used. The strategies are arranged from least complex to most complex. In general, the level of pathogen control increases from Strategy 1 to Strategy 7.

**Strategy 1: sanitation control.** Cross-contamination of meat and poultry is minimized by regular sanitation of the conveyor belts and other equipment in the plant. Systematic cleaning of the plant's walls, drains, and air ventilation at regular intervals further reduces risk. Although HACCP requires certain sanitation practices,

firms may choose to comply minimally (or do nothing) until receiving notice of a regulatory violation.

**Strategy 2: kill step for pathogens.** A firm decontaminates food at the end of the production line, for example pasteurizing milk, canning fruits, or irradiating hamburger patties in case-ready packages for sale in supermarkets.

**Strategy 3: pathogen prevention.** A firm prevents pathogens from entering the plant at one or more locations, keeps pathogens from growing on food through control over temperature and shelf-life, and minimizes cross-contamination between food products and between the plant environment and food products.

**Strategy 4: multiple-hurdle approach.** A firm improves control over all operations in the plant, or at least at several prevention and decontamination steps. This is similar to the standard practice in food companies for designing new foods with several barriers or hurdles to keep pathogens from surviving or growing in foods.

**Strategy 5: key risk locations.** A firm uses microbial testing at various locations in the plant to determine where the highest probability of pathogen contamination occurs. Pathogen data are used to identify key risk locations, where managers improve pathogen control using new processes and employee training. Or, the data can be put into a risk model and various control scenarios evaluated to determine key risk locations and effective control strategies.

**Strategy 6: compare risk/cost tradeoffs.** A firm adds explicit consideration of the costs of alternative control options to Strategy 5 and evaluates the risk/cost tradeoffs of different control options.

**Strategy 7: invest in R&D.** A firm adopts a long-run strategy to invest in research and development and invent new control options, either by adapting management systems or processes used in a related industry or by inventing a new management system or process (complete with new equipment) to control pathogens.

What empirical evidence exists about the pathogen-control strategies used by firms? Case studies reveal what strategies are used and present evidence of the high information costs of pathogen control, joint production functions, and incentives for innovation.

### *New Testing and Management System*

The Bacterial Pathogen Sampling and Testing Program (BPSTP) was invented by the Texas American Foodservice Corporation (Golan et al., 2004). Developed in collaboration with four other partners, the BPSTP demonstrates the evolving market incentives for pathogen control. In the early 1990s, Texas American tightened its quality-control procedures in response to increased product returns and customer complaints about hamburgers contaminated with fragments of plastic or metal.

In 1993, Jack in the Box was hit with a major outbreak associated with *E. coli* O157:H7 in its hamburger patties. For Texas American, Jack in the Box's offer of a negotiated contract for successful pathogen control in hamburger patties offered the opportunity to intensify the company's new commitment to safety and quality assurance. With the contract, Texas American was able to reduce its sales in the spot market. The contract permitted more efficient use of equipment and more efficient scheduling of the workforce as well as reduced product spoilage and product returns due to spot market sales. These production cost savings were transferred into development of the BPSTP pathogen control program.

The BPSTP is a process innovation combining a new sampling protocol/management system for *E. coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* and a new application of a patented testing technology to hamburger patty processing lines. The process innovation has resulted in a product innovation: hamburger patties with consistently low levels of pathogen contamination. Both companies were first motivated by the need for risk management to limit or eliminate the damage in reputation, sales, and liability stemming from inadequate quality control. Both companies have found that leadership in pathogen control has been a foundation for growth.

The food-safety strategy used in this example was Strategy 5 (control at key risk locations) in combination with Strategy 7 (invest in R&D to develop a new management system). The joint production function for economic efficiency and pathogen control were also exhibited. The inaccuracy of pathogen information drove Texas American to collaborate with Qualicon, a company developing a superior test (BAX) for detecting *E. coli* O157:H7 in beef.

### *Innovative Equipment*

Frigoscandia Equipment invented the Beef Steam Pasteurization System (BSPS) to sterilize the exterior of beef carcasses in collaboration with beef industry and academic partners (Golan et al., 2004). The BSPS technology uses steam to kill pathogens on beef carcasses. The BSPS unit is in

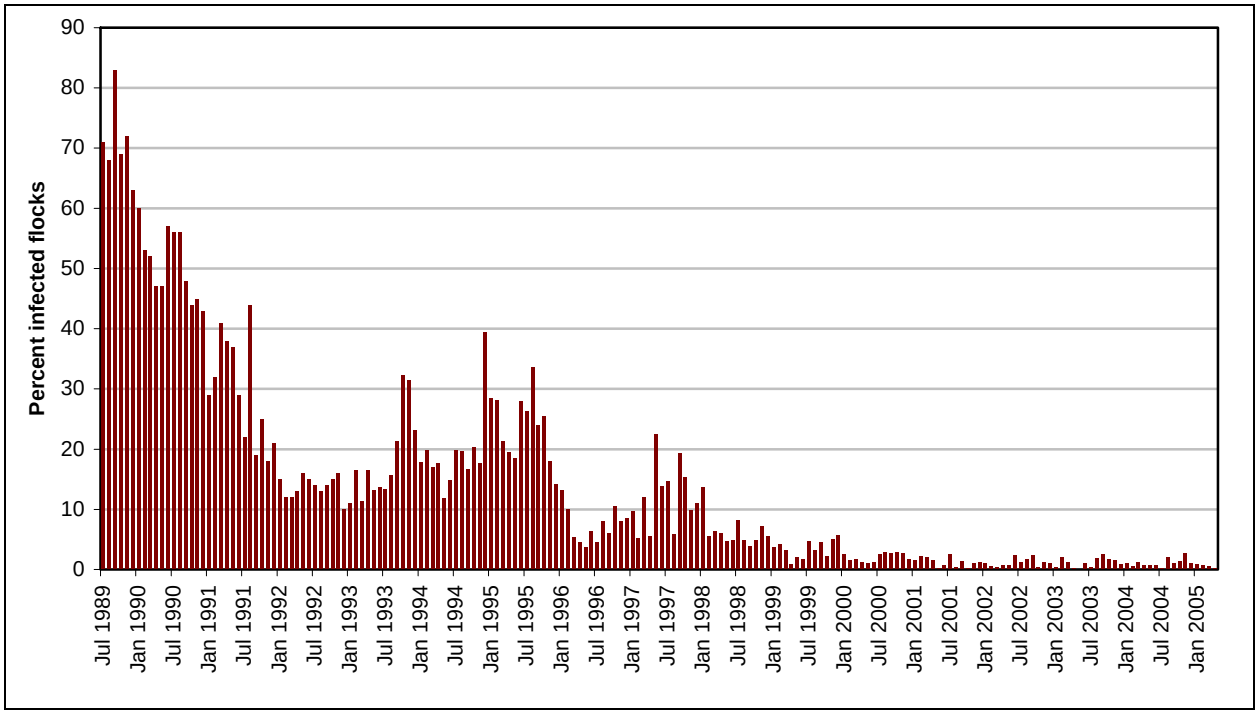


**Figure 1.** *Salmonella* in Danish broiler flocks as determined by bacteriologic testing of every flock 2–3 weeks before slaughter ($N$ > 4,000 flocks/year).
Note. Data from Wegner et al. (2003).

a stainless steel cabinet at the end of the slaughter line before the sides of beef (hanging from an overhead rail) enter the chiller. The BSPS can be purchased with automatic record-keeping capabilities for carcass identification, steam temperature, steam exposure time, and deviations. For companies selling equipment to meat processors, a central information question is validating the ability of the equipment to kill pathogens. Efficacy, however, is linked to other downstream actions; for example, a poorly run chilling procedure can negate the benefits of the BSPS, as cross-contamination and pathogen recovery and growth can occur. Other issues in equipment sales are the uncertainty about the level of safety required by the marketplace or government regulations.

In inventing the BSPS, Frigoscandia Equipment was using Strategy 6—invest in R&D for sales to other companies. The BSPS illustrates Strategy 2—the kill step for pathogens (if the steam temperature is high enough and the steam time is 20–30 seconds). The joint production function problem occurs in two ways: (a) if the steam is applied for too short a time, perhaps to save money, efficacy in killing pathogens can be compromised, or (b) if the steam is applied long enough to kill virtually all pathogens, the tradeoff is some cooking on the carcass exterior. Information uncertainty is a large issue, especially because downstream controls must be rigorous to maintain the high level of pathogen control.

### *Employee-Run Electronic Continuous Monitoring*

By turning over monitoring of the the production line to employees, Hatfield Quality Meats in Pennsylvania reduced the defect levels on pork carcasses from 8% to 1% over four years (Bolton, Oser, Cocoma, Palumbo, & Miller, 1999). The program first enforced job pride—a strong factor in the success of the system. The on-line monitoring was able to identify when intensive training was needed to improve evisceration practices, when engineering problems called for redesign of operating practices, and when feed-withdrawal practices for hogs needed modification. Implementation resulted in less trimming and less product waste and required fewer employees. The plant may have saved money, even though there were training and equipment costs. Food safety increased dramatically: Microbial contamination levels decreased 99.8% to less than half the US national average level for pork.

This case study illustrates the benefit of improved information in food safety. Joint production function issues were exhibited. Hatfield Quality Meats used Strategy 5—monitoring and identification of key risk locations on the slaughter line.

### *Hog Total Confinement Production System*

Using data from the National Animal Health Monitoring System survey, Wang et al. (2002) compared traditional US hog production systems (barns, sheds, and access to the outdoors) to total confinement systems. They found traditional production had slightly higher long-run production costs: $0.31/cwt for hogs. Although the confinement buildings were more expensive, costs were more than offset by greater feed and bedding costs in nonconfinement production. Analysis of blood samples found that total confinement market hogs had a statistically significant lower level of contamination with the parasite *Toxoplasma gondii*, a human pathogen.

This case study illustrates three points: (a) the joint production function of economic efficiency and parasite control in a total confinement production; (b) the information problem in linking the human illness (toxoplasmosis) to pork consumption that causes weak economic incentives to switch to confinement systems for pathogen control; and (c) use of Strategy 4 (the multiple-hurdle approach) to use a combination of methods to limit cat and rodent access to hogs and reduce contamination of hogs with *Toxoplasma gondii.*

### *Salmonella Control in Danish Broilers*

Wegener et al. (2004) found that government-mandated *Salmonella* control programs of broiler chickens were successful five years after implementation (Figure 1). The control strategy used extensive pathogen testing of feed supplies and of birds in quarantine, in the hatchery, on the farm, and in the slaughterhouse. The pathogen test data were used to identify *Salmonella*-control problems and execute changes in the production chain, such as destruction of all *Salmonella*-contaminated birds and feed.

Farmers were initially indemnified for contaminated broilers, but private insurance is required now, and high-risk farmers pay increased premiums—a strong incentive for *Salmonella* control. An economic incentive available to retailers is a "*Salmonella*-free" label for broilers sold in Denmark. This study illustrates how a combination of government regulations and private requirements for pathogen-insurance coverage can overcome the information problem related to pathogen control.

The primary strategies used were a combination of Strategies 3, 4, and 5. Pathogens are prevented when *Salmonella* tests are required throughout the supply chain. When contamination is detected, immediate actions are taken, such as destruction of *Salmonella*-contaminated birds and feed and effective cleaning of all contaminated facilities documented by environmental testing. This case study also reveals the importance of strong regulatory controls that are enforced.

## Choices About Achieving Greater Pathogen Control

Food safety is an example where weak market incentives are changing with new information about pathogen risks and controls. In the last decade, foodborne disease outbreaks and surveillance, new pathogen tests, and new regulations have strengthened private incentives for pathogen control. Supply chain managers face a steep learning curve to control bacteria that can multiply in the food chain. Public policy makers have been challenged by how to get the economic incentives right. Innovation has occurred in both public and private management strategies, resulting in positive change in both sectors. HACCP and its enforcement procedures are a step toward new pathogen control policies. The focus of this paper, however, is the strategies used by private companies to control foodborne pathogens.

The five case studies displayed an array of innovative management systems (e.g., the hamburger patty plant), superb supply chain control that extended back to the grandparents of broilers, and employee empowerment to control pathogens (e.g., the pork plant). Although weaker incentives to control pathogens were exhibited in hog confinement production and the beef carcass steam pasteurization equipment case studies, significant pathogen control was nonetheless within economic reach of private firms.

The strong role that public policies play in providing incentives to firms is illustrated by the Danish requirements for *Salmonella* control in broilers. Especially noteworthy is the system of initially compensating farmers for contaminated broilers, then phasing this system out and replacing it with private insurance. In the last decade, there has been continuous improvement by both public regulators and private companies in pathogen control. Some private companies are taking the concept one step further to create continuous innovation in pathogen control and using this as a marketing strategy.

## For More Information

Akerlof, G. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, *84*(3), 488-500.

Bolton, D., Oser, A., Cocoma, G., Palumbo, S., & Miller, A. (1999).

Integrating HACCP & TQM reduces pork carcass contamination. *FoodTechnology*, *53*(4), 40-43.

Golan, E., Roberts, T., Salay, E., Caswell, J., Ollinger, M., & Moore, D. (2004). *Food safety innovation in the United States: Economic theory and empirical evidence from the meat industry* (Agricultural Economic Report No. AER831). Washington, DC: United States Department of Agriculture Economic Research Service. Available on the World Wide Web: http://www.ers.usda.gov/publications/AER831/.

Malcolm, S., Narrod, C., Roberts, T., & Ollinger, M. (2004). Evaluating the economic effectiveness of pathogen reduction technology in beef slaughter plants. *Agribusiness: An International Journal*, *20*(1), 109-123.

Mazzocco, M. (1996). HACCP as a business management tool. *American Journal of Agricultural Economics*, *78*(3), 770-774.

Metcalf, S. (1995). The economic foundations of technology policy: Equilibrium and evolutionary perspectives. In Paul Stoneman (Ed.), *Handbook of the Economics of Innovation and Technological Change* (pp. 410-512). Oxford, UK: Blackwell Publishers Ltd.

Ollinger, M., & Ballenger, N. (2003, April). Weighing incentives for food safety in meat and poultry. *AmberWaves*, 1(2), 34-41. Available on the World Wide Web: http://www.ers.usda.gov/Amberwaves/April03/Features/WeighingIncentives.htm.

Ralston, K., Brent, C., Starke, Y., Riggins, T., & Lin, C.T. (2002). *Consumer food safety behavior: A case study in hamburger cooking and ordering* (Agricultural Economic Report No. AER804). Washington, DC: United States Department of Agriculture Economic Research Service. Available on the World Wide Web: http://www.ers.usda.gov/Publications/aer804/.

Roberts, T., Ahl, A., & McDowell, R. (1995). Risk assessment for foodborne microbial hazards. In *Tracking Pathogens from Farm to Table: Data Needs to Evaluate Control Options*. (MP 1532; pp. 95-115). Washington, DC: United States Department of Agriculture Economics Research Service. Available on the World Wide Web: http://www.ers.usda.gov/publications/MP1532/mp1532.pdf.

Unnevehr, L. (2003). Food safety: Setting and enforcing standards. *Choices*, *18*(1). Available on the World Wide Web: http://www.choicesmagazine.org/2003-1/2003-1-03.htm.

Unnevehr, L. (2004). Mad cows and Bt potatoes: Global public goods in the food system. *American Journal of Agricultural Economics*, *86*(5), 1159-1166.

Unnevehr, L., Roberts ,T., & Custer, C. (2004). New pathogen testing technologies and the market for food safety information. *AgBioForum*, *7*(4), 212-218.

Wang, C.-H., Diderrich, V., Kliebenstein, J., Patton, S., Zimmerman, J., Hallam, A., et al. (2002). *Toxoplasma gondii* levels in swine operations: Differences due to technology choice and impact on costs of production. *Food Control*, *13*(2), 103-106. Available on the World Wide Web: http://www.sciencedirect.com/science/journal/09567135.

Wegener H.C., Hald T., Wong D.L.F., Madsen M., Korsgaard H., Bager F., et al. (2003). *Salmonella* control programs in Denmark. *Emerging Infectious Diseases*, *9*(7), 774-780. Available on the World Wide Web: http://www.cdc.gov/ncidod/EID/vol9no7/03-0024.htm.

*Without implicating them for the paper's shortcomings, the author appreciates insightful comments from Mike Doyle, Andrew Starbird, and two anonymous reviewers.* *Tanya Roberts is with the Diet, Safety and Health Economics Branch in the Economic Research Service, United States Department of Agriculture. The views expressed in this article are not necessarily those of the USDA.*