Part II. Empirical Investigation: A Closer Look at Food Safety Drivers in the Meat Industry

The theoretical literature suggests that failure in markets for food safety may dampen two of the primary drivers of innovation: appropriability and market demand. Because safety is a credence attribute, firms may have difficulty appropriating the benefits of food safety innovation—and given the graphic nature of many safety attributes, even firms with the safest records may have little incentive to disclose their records, if it means raising consumer concerns about food safety. In addition, firms may actually avoid establishing appropriability, if it also entails an increased likelihood of facing liability when food safety problems arise. On the demand side, consumers are largely unknowledgeable about food safety practices and tend not to demand product differentiation on the basis of food safety.

With little incentive for safety disclosure on the part of firms, and episodic demand from consumers, it is almost surprising that any firms invest in improved food safety and continue to innovate to improve food safety. Yet they do. How do they overcome the disincentives discussed above?

To investigate this question, we turn to evidence from the meat industry. The meat industry is an important industry in which to investigate these questions for three reasons. First, though our meat products are some of the safest in the world, food safety remains a critical issue within the industry. Meat and poultry are estimated to be responsible for more than 40 percent of human illnesses associated with four common pathogens (USDA, 1996, p. 733). The meat industry has also experienced a number of large, well-publicized recalls and has been at the heart of some of the Nation's most tragic foodborne illness outbreaks (see box "The 1993 Jack in the Box Restaurant *E. coli* O157:H7 Outbreak").

Second, controlling pathogen contamination in meat production, particularly ground meat production, is a challenging task. Pathogens can be introduced and or amplified at many stages along the production, processing, and retailing chain (Roberts, Ahl, and McDowell, 1995). Farm inputs may bring pathogens onto the farm, and production practices on the farm may increase pathogen numbers, as well as expose food animals to new pathogens. Transportation may cause stress in animals, increasing shedding and the spread of pathogens. Slaughtering procedures may spread pathogens among animals, carcasses, and cuts of meat. Processing and product fabrication may encourage the growth of existing pathogens and introduce new pathogens through worker handling, ingredients, poor temperature control, and the water used in processing. Hamburger production, in which scraps of meat are ground into a homogeneous product, introduces the potential for integrating pathogens throughout the product. The transportation of meat products to wholesale/retail operations may result in pathogen growth, cross-contamination of products, or introduction of new pathogens. How foods are stored and displayed affects pathogen growth through temperature control, possibilities for cross-contamination, and length of shelf-life. How food is handled in the kitchen affects the probability that pathogens multiply or cross-contaminate other products. Hamburgers that are not thoroughly cooked may harbor pathogens in the interior of the patty.

The challenge of controlling pathogens in meat production makes the industry particularly fertile ground for food safety innovation: the potential for killing or controlling pathogen growth exists at all or most points along the production chain. This potential, along with technological and methodological advances in pathogen control, contributes to making the meat industry particularly interesting for a study on food safety innovation. The development of new tests for microbial pathogens has created additional options for detecting unwanted pathogens associated with meat. Improved analytical tools for risk assessment, new processes and equipment to kill pathogens, as well as new procedures and management systems to control pathogens, have all led to reduced levels of pathogen contamination and greater efficiency in pathogen control at many different stages in the meat production chain.

The third reason the meat industry is an important industry in which to examine food safety innovations is its size and diversity. The Food Safety and Inspection Service of USDA (FSIS) and State inspection agencies monitor about 2,500 establishments that process meat or poultry products as their primary business activity.[2]

[2] Together, FSIS and State agencies monitor over 9,000 plants producing meat and poultry products. However, the vast majority of these plants have other businesses that are much larger than their meat and poultry operations. The Bureau of the Census identifies a little more than 3,000 manufacturing plants producing meat and poultry products. Of those plants, we estimate that only about 2,500 have meat or poultry manufacturing as their primary line of business.

The 1993 Jack in the Box Restaurant *E. coli* O157:H7 Outbreak

In 1993, a Seattle pediatrician noticed an unusual spike in the number of children with bloody diarrhea. He alerted Washington State health officials about a possible foodborne disease outbreak. Within a week of documenting the diarrheal disease outbreak, health department investigators identified *E. coli* O157:H7-contaminated hamburgers from Jack in the Box restaurants as the cause. In all, 73 Jack in the Box restaurants in the States of Washington, Idaho, California, and Nevada were involved in the outbreak and recall. Seven hundred people became ill and four children died. Epidemiologists at the Centers for Disease Control and Prevention concluded that the outbreak resulted from errors in meat processing and cooking (Bell et al., 1994).

Epidemiologists had been following *E. coli* O157:H7 since 1982, when the pathogen was first linked to human illness in a two-State outbreak associated with hamburgers from McDonald's (Bryan et al., 1994). They soon discovered that the *E. coli* pathogen had interacted with *Shigella*, a well-known, virulent pathogen, to develop the ability to produce the toxin causing the human illnesses. In 1985, epidemiologists documented *E. coli* O157:H7 as the leading cause of acute kidney failure in children, and in 1992 they concluded that it was the most common bacterial cause of bloody diarrhea.

The 1993 Jack in the Box *E. coli* O157:H7 outbreak marked an important turning point in epidemiologists' approach to *E. coli* O157:H7 and infectious disease in general (Editor, 1993). Before the outbreak and the full-blown emergence of *E. coli* O157:H7 as a foodborne pathogen, many epidemiologists had predicted that the discovery of sulfa and penicillin would eliminate infectious diseases as a public health problem.

Repercussion from the outbreak—and the newly recognized public health threat—were widespread. Within the 18 months following the outbreak, the Jack in the Box company lost approximately $160 million in reduced sales and other costs (Roberts et al., 1997). These costs included those associated with the company's voluntary recall of all hamburger meat from their restaurants. They also included legal costs. A number of ill customers and parents of ill or dead children filed suits against Jack in the Box and its parent company, Foodmaker, Inc. All cases were settled out of court, with one family receiving over $15 million for a child who was brain damaged. Stockholders also filed suit against the company for court costs and lost sales due to adverse publicity.

The Federal Government responded to the Jack in the Box outbreak in several ways. President Clinton signaled the importance of the outbreak by sending the Secretary of Agriculture to testify before the Washington State legislature. The Food and Drug Administration (FDA) raised the recommended internal temperature for hamburgers cooked in restaurants to 155º F. USDA's Food Safety and Inspection Service (FSIS) initiated several programs after the outbreak: a safe-food-handling label with instructions for consumers on packages of raw meat and poultry sold in supermarkets, an information campaign alerting school children to eat hamburgers cooked well-done, and tests for *E. coli* O157:H7 in raw ground beef prepared in federally inspected establishments and in retail stores. FSIS also changed the status of *E. coli* O157:H7, declaring it an adulterant in raw ground beef. As a result of the outbreak, the Centers for Disease Control and Prevention (CDC) obtained additional funding for its FoodNet program to identify foodborne pathogens causing intestinal illness. The outbreak also accelerated efforts to modernize Federal requirements for food safety using the Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP) system (see box "Pathogen Reduction and Hazard Analysis and Critical Control Point Program, p. 14").

The outbreak united parents of those children who had become ill in the outbreak to create the first consumer activist group devoted to food safety, Safe Tables Our Priority (STOP). STOP has been a very visible lobbying group for safer food at congressional and USDA hearings, at professional conferences, and in the media (for example, see Eskin et al., 2003).

The 1993 outbreak also spurred the beef industry to fund research. The Washington Beef Commission supported research on techniques for detecting *E. coli* O157:H7 in hamburger (Bell et al. 1994) and the National Cattlemen's Beef Association (NCBA) set up a task force to fund research on how to reduce *E. coli* O157:H7 in cattle and slaughterhouses, as well as how to establish testing and sampling programs to detect the pathogen. The interventions developed by the NCBA have a high rate of adoption by the industry (Smith, 2003). The NCBA spends an average of $2.5 million on food safety research and technology each year (Voldseth, 2002). In early 2003, NCBA helped form a new committee, the Beef Industry Food Safety Council (BIFSCo), with representatives from all segments of the beef industry. BIFSCo's mission is to develop industry-wide, science-based strategies to solve the problem of *E. coli* O157:H7 and other foodborne pathogens in beef (Beef Food Industry Safety Council, 2003).

These establishments can be grouped into five categories: producers of cooked or otherwise further processed products with no slaughter operations; raw meat processors with no slaughter operations; and cattle, hog, and poultry slaughter plants. Some slaughter plants engage in a wide range of processing, and some cattle slaughter plants slaughter animals other than cattle, including hogs, sheep, and goats.

The main products of cooked meat processors include roast beef and other cooked meats, luncheon meats and frankfurters, bacon and other smoked products, pepperoni and other fermented products, and raw meat products. Raw meat processors with no slaughter operations produce mainly ground beef and pork, fabricated cuts, and other raw products. Carcasses and hamburger and other boneless beef are the chief products of cattle slaughter plants while carcasses and cooked and other further processed products are the main outputs of hog slaughter plants. Poultry plants, in contrast to hog and cattle slaughter, sell mainly cut-up products (about half of their output) and products processed beyond cut-up (about a quarter of their output).

In 1997, the meat and poultry industry supplied about $110 billion of output. Cattle and hog slaughtering was by far the largest sector, accounting for about half of industry output. Poultry slaughter and processing amounted to about $31 billion in sales, while cooked and raw meat processors without slaughter operations accounted for the final quarter of industry output. Cattle and hog slaughter plants were also more numerous than poultry slaughter plants, with 1,400 plants and over 140,000 employees. Poultry slaughtering had about one-third the number of plants, but, due to the much larger size of its plants, employed about 225,000 workers in 1997. There were also a large number (about 1,300) of raw- and cooked-meat processors but they employed only about 90,000 workers (Bureau of the Census, 1999 a, b, and c).

The cattle slaughter industry, the focus of the case studies, had an output of about $28 billion in 1997, the vast majority of which was supplied by the 300 federally inspected plants (USDA, FSIS, 1999). The industry has become increasingly concentrated in the last three decades, with its four-firm concentration ratio (the share of the industry's output held by the four largest producers in the industry) exhibiting a dramatic increase from 1963 to 1992 (table A-2). The growth of large cattle slaughter plants during this period is also striking. Table A-3 shows that the percent of animals slaughtered in large plants grew from 12 percent in 1977 to 65 percent in 1997 (MacDonald et al., 2000). Eighty percent of steers were slaughtered in large plants in 1997. Table A-4 shows that over the 1977-92 time period, large plants' share of industry value of shipments grew from 31 percent to 72 percent (MacDonald et al., 2000).

Large cattle slaughter plants differ from small plants in more than just the volume of production. They also vary with respect to the diversity of inputs and outputs, with smaller plants processing a more diverse set of animals and products than large plants. A recent survey of cattle slaughter plants found that smaller plants slaughtered hogs and other animals such as sheep and goats while larger plants slaughtered only cattle

Table A-2—Four-firm concentration ratios, value of shipments basis

	Slaughter industry			
Year	Cattle	Hogs	Chickens	Turkeys
1963	26	33	14	23
1967	26	30	23	28
1972	30	32	18	41
1977	25	31	22	41
1982	44	31	32	40
1987	58	30	42	38
1992	71	43	41	45

Source: MacDonald et al. (2000).

Table A-3—Percent of animals slaughtered in large plants

	Slaughter classes (size cutoff[1])					
Year	All cattle (500,000)[1]	Steers (500,000)[1]	Heifers (1 million)[1]	Cows/bulls (150,000)[1]	Hogs (1 million)[1]	Sheep/lambs (300,000)[1]
1977	12	16	nr	10	38	42
1982	28	36	nr	15	59	73
1987	51	63	31	20	72	84
1992	61	76	34	38	86	74
1997	65	80	60	62	87	75

[1]The size cutoff, in parentheses, refers to the minimum number of animals slaughtered annually in the large plant category.

Source: MacDonald et al. (2000).

Table A-4—Large plants' share of industry value of shipments[1]

Year	Slaughter industry			
	Cattle	Hogs	Chickens	Turkeys
1963	31	66	d[2]	d[2]
1967	29	63	29	16
1972	32	62	34	15
1977	37	67	45	29
1982	51	67	65	35
1987	58	72	76	64
1992	72	86	88	83

[1]Large plants are defined as those with more than 400 employees.
[2]Data cannot be disclosed, in order to retain respondent confidentiality.

Source: MacDonald et al. (2000).

(table A-5). Smaller plants also processed more meat into further processed products than did larger plants. Larger plants preferred to sell trim products to other processors for further processing (table A-6).

To investigate drivers of safety innovation in the meat industry, we first examine recently completed survey data of U.S. meat and poultry slaughter and processing plants. These data reveal the characteristics of firms that do and do not innovate or adopt new food safety technologies or methodologies. This information helps to reveal the incentives and constraints to food safety innovation and imitation in slaughter and processing plants. We then turn to two case studies of innovation in the beef industry. The first case study examines the development and marketing of a new food safety technology. The second examines the development of a microbial management system for hamburger patties.

Table A-5—Annual animal inputs per plant by plant size for cattle slaughter plants[1]

	Small plants[2]	Medium plants[2]	Large plants[2]
		Number of animals	
Cattle	161	3,448	191,781
Hogs	387	4,178	0
Other animals (mostly sheep and goats)	36	1,000	0
Number of plants	28	95	30

[1] Animal inputs based only on plants reporting one or more animal input.
[2] Plant size categories by percentile of output: plants in small category produced 19 percent of total industry output; plants in medium category 20-79 percent of total industry output; and plants in large category produced 80-100 percent of total industry output.

Source: Food Safety Inspection Service, Enhanced Facilities database and the Economic Research Service, Food Safety Technology and Practices and HACCP costs survey.

Table A-6—Product output share by plant size for cattle slaughter plants[1]

	Small plants[2]	Medium plants[2]	Large plants[2]
Raw meat products			
Carcasses	22.0	29.2	26.3
Ground beef	19.2	15.8	11.2
Trim or other boneless beef or pork	14.8	18.0	27.9
Sub-primal and fabricated cuts	10.2	14.9	15.2
Other raw-meat products	8.0	8.2	9.3
Cooked or otherwise further processed products	25.8	31.9	9.1
Mean pounds of output (1,000 pounds per year)	186	7,860	260,127
Number of plants	28	95	27

[1] Average output shares are based on all reporting plants.
[2] Plants in the small category are in the 0-19 percentile of plant sizes; plants in medium category are in the 20-79 percentile; and plants in large category are in the 80-99 percentile.

Source: Ollinger, Moore, and Chandran (forthcoming).