Part I. Theory: The Economics of Food Safety Innovation

Food Safety Innovation Boosts Social Welfare

Innovation is all the scientific, technological, organizational, financial, and commercial activities necessary to create, implement, and market new or improved products or processes (OECD, 1997). Innovation takes two forms: product innovation and process innovation.

A *product innovation* is the development and commercialization of a product with improved performance characteristics (OECD, 1997). Product innovation tends to expand consumer choice. More product choice allows more consumers to find products that better match their particular tastes and preferences, thereby expanding consumer welfare. This welfare-increasing effect of product innovation is not guaranteed, however. Product innovations that become the industry or regulatory standard may ultimately reduce, not increase, product differentiation and consumer welfare. For example, some cities prohibit sales of unpasteurized milk, thereby reducing choice through the elimination of raw milk markets.

A *process innovation* is the development or adoption of a new or significantly improved production or delivery method (OECD, 1997). Process innovations may be technological or organizational, involving changes in equipment, human resources, working methods or any combination of these. Process innovation tends to make production more efficient. With diffusion, some or all of these efficiency gains may be passed on to consumers in the form of lower prices. Social welfare is improved through lower prices and more efficient use of resources.

The distinction between product and process innovation for food safety is not clear cut because food safety process innovations often lead to safer foods, not just the same level of safety at less cost. Pasteurized milk, juices, and eggs, ultra-high temperature (UHT) milk, and irradiated spices and meat patties encompass technological innovations that have made standard food products safer. Even such processing changes as properly refrigerated trucks, lot coding, lay-date stamping on eggs, pathogen testing, and instant-read thermometers all lead to safer final products, blurring the line between process and product innovation.

Imitation plays an important role in ensuring that the benefits of innovation, whether product or process, are maximized. Imitators, those firms that adopt and adapt innovations pioneered by other firms, help ensure that the choice and efficiency gains of innovation are realized. Product innovations that are widely marketed have a bigger impact on consumer choice than those with limited market exposure. Process innovations that are widely adopted or account for a large share of industry output have a larger impact on industry efficiency and consumer welfare than those with limited use.

Widespread diffusion of food safety innovation not only increases choice and economic efficiency, it also saves lives and improves health. In 1999, the U.S. Centers for Disease Control and Prevention estimated that annually, one in three Americans become ill from a foodborne illness, one in 700 are hospitalized, and one in 60,000 die (Mead et al., 1999). The human toll is mirrored by an economic one. USDA's Economic Research Service estimates that the annual economic cost of five foodborne illnesses[1] is approximately $6.9 billion per year (ERS, 2001). Innovation and the adoption and diffusion of food safety improvements will help combat foodborne illness and improve the quality of life for all Americans.

Appropriability, Market Demand, and Technological Opportunity Are Key to Innovation

How can policymakers and regulators encourage food safety innovation to improve public health and expand social welfare? Why do some policies succeed in stimulating food safety innovation for some firms but not for others? To begin to answer these questions, we first turn to the general economics literature. Economists and business analysts have spent well over half a century investigating the questions of "What drives firms to innovate?" and "What differentiates innovating from non-innovating firms?"

[1] The five pathogens included in the ERS estimate are *Campylobacter*, *Salmonella* (nontyphoidal serotypes only), *E. coli* O157:H7 and non-O157 STEC, and *Listeria monocytogenes.*

A starting point for much research on innovating behavior is Schumpeter's work on growth and innovation (Schumpeter, 1934 and 1942). His assertion that large firms operating in concentrated markets are the best engines of technological progress motivated early innovation researchers to focus their investigations on the role of firm size and market concentration. Only relatively recently have researchers expanded the investigation to examine other factors, eventually identifying appropriability (the ability to control and exploit the benefits from innovation), market demand, and technological opportunity as the core drivers for innovation and technological change. In this section, we outline how these core drivers of innovation operate in most industries and then examine their operation in the food industry for food safety innovation. For more complete reviews of the innovation literature, see Freeman (1994), Cohen (1995), and Stoneman (1995). Pray and Fuglie (2000) examine the literature on the drivers of innovation in agriculture.

Appropriability

Appropriability, the ability to control and exploit the benefits from innovation, plays a key role in driving investment in innovation. Only if firms expect to be able to reap the benefits of an innovation will they have an incentive to innovate. This principle was articulated by Schumpeter when he argued that the expectation of ex-post market power is an important inducement to innovation (Schumpeter, 1942).

Early researchers, including Schumpeter, argued that bigger, diversified, oligopolistic firms are typically in a better position to appropriate the benefits of innovation than smaller, specialized, firms without market power. This is more likely to be the case when the most efficient mechanism for appropriating the benefits of innovation is through a firm's own output. However, when other means of appropriation are as effective, then size, degree of diversification, and ex-ante market power are joined by other firm and industry characteristics in predicting a firm's potential for appropriating the benefits of innovation—and therefore, for predicting which firms will invest in innovation.

Supply chain management, patents, branding, marketing, customer service, secrecy, early sale of innovative rights, and first-mover advantage all provide varying degrees of protection from competition and help firms appropriate the benefits of innovation. Firms that successfully develop any of these appropriation mechanisms will be better able to capture benefits from innovation, and therefore have more incentive to innovate, than firms that are unable to create these mechanisms. Firms may use any of these mechanisms. In their survey of American firms (the first comprehensive survey of appropriability conditions in the U.S. manufacturing sector), Levin et al. (1987) found that 80 percent of surveyed firms regarded investments in complementary sales and services as an effective means to protect returns to innovative investments. Many of the firms in the Levin et al. survey stated that a head start and the ability to move quickly down the learning curve were more effective means of appropriation than patents. Peculiarities of the industry, firm, and even the type of innovation interact to determine the most efficient means of appropriation and the firms that are most successful in establishing them.

The importance of appropriability in motivating innovative activity extends to every manager and worker in the firm or plant. Managers and workers who are able to appropriate some of the benefits of innovative activity will be more likely to initiate and engage in such activity. Subtle firm-level characteristics such as the organization of product development, information processing capabilities, and internal organization may have a strong effect on the appropriation structure within the firm and the incentives of individual workers to engage in innovative activity. This observation echoes one made by Schumpeter in his discussion of the delusory effect of hierarchical management systems on managerial initiative. He argued that managers who do not have some control over the product of their labor will lose the incentive to innovate.

Demand

The view that market demand has an almost exclusive pull on innovation was staked out by Schmookler in his work on the determinants of technical change (Schmookler, 1962 and 1966). He argued that demand determines the rate and direction of inventive activity because rational, profit-seeking firms are responsive to economic incentives. Schmookler argued that there is a general pool of knowledge and technical capability, and that only those industries driven by market demand are motivated to dip into the pool and adapt technologies to their own purpose. Market demand provides the incentive to firms to innovate and adapt technologies.

To test Schmookler's hypothesis, researchers have primarily examined intermediate products, demand for

which is derived from estimates of final demand and the downstream production technology. Though Schmookler's own empirical investigation found that demand played a major role in driving innovation (Schmookler, 1966), subsequent researchers have not duplicated this result. In general, the empirical evidence has not identified demand to be a key determinant of innovation (Cohen, 1995).

Though demand may not directly spur innovation, researchers have suggested two principal ways in which demand conditions may influence innovative activity. First, the size of the market may influence innovation because even if innovative activity is scale neutral, the benefits of innovation are proportional to the size of the market. In other words, holding constant the cost of innovation, more innovative activity would be expected in the larger market or in the market expected to grow more rapidly.

Second, the elasticity of demand may also play a role in determining the level of innovation. Kaimen and Schwartz (1970) demonstrated that the gains from process innovation are larger when demand is more elastic. Process innovation lowers production costs, thereby shifting out the supply curve. Movements of the supply curve result in larger quantity changes and smaller price changes, the more elastic the demand. As a result, process innovation triggers larger increases in producer surplus when demand is more elastic. The effect of demand elasticity on the gains from product innovation is less straightforward. Market structure and the degree to which consumers view the new and old products as substitutes determine gains from product innovation more than do existing demand elasticities. (For an introduction to this literature, see Carlton and Perloff, 1994.)

Technological Opportunity

Contrary to Schmookler's position, the "technology-pull" hypothesis posits that the direction and rate of technological change is determined not by demand, but by the suitability of the technology to a particular industrial application. In general, the empirical evidence tends to support this hypothesis, finding that cost and applicability of design are as important as, or more important than, demand considerations (Cohen, 1995).

The existence or growth of scientific knowledge encourages innovation through a number of avenues. First, the cost of undertaking a science-based innovation may decrease as scientific knowledge increases. A strong scientific base focuses innovative activities in the most productive direction, reducing the costs of trial and error. Second, a strong scientific base may provide a rich pool of potential technologies, thereby increasing the likelihood of finding a technology efficiently suited to a firm's or industry's specific objectives. Third, a strong scientific base may actually increase a firm's or industry's set of objectives, decreasing innovation costs by expanding the set of problems with solutions.

The development of technologies is often completely divorced from demand considerations—though applications triggered by initial technological breakthroughs are often motivated by demand conditions. In many cases, a major innovation triggers a series of smaller innovations tailored to the specific needs of a particular firm or industry (Walsh, 1984). For example, the scientific research behind the harnessing of electron beams, x-rays, or gamma rays was not motivated by the demand for pathogen control in food processing. However, demand for food safety has motivated the application of irradiation technologies for controlling pathogens and improving the safety of a variety of foods. Irradiation technologies have been developed to control pathogens and fungi in spices and dried vegetable seasonings, to delay ripening and sprouting in fresh fruits and vegetables, and to control pathogens and extend shelf-life of raw meats and meat products (ERS, 2003).

Changes in Appropriability, Demand, and Technological Opportunity Vary the Costs and Benefits of Innovation and Imitation

As outlined above, the theoretical and empirical economics literature points to appropriability, market demand, and technological opportunity as the key factors affecting the costs and benefits of innovation. The strength of these factors helps to tip the balance toward innovation for some firms and away from innovation for others. Strong appropriability mechanisms, large potential markets, elastic demand, and innovations that are easily adaptable to firm-specific applications all increase the benefits of innovation, tipping the innovation cost-benefit calculus toward innovation. Table A-1 illustrates how these three factors condition a firm's innovation cost-benefit calculus.

Appropriability, market demand, and technological opportunity also play key roles in a firm's decision to

Table A-1—Economic literature suggests three main drivers of innovation and imitation

	Innovation	Imitation
Appropriability	+ The stronger the ability of innovators to appropriate the benefits of innovation, the higher the likelihood of innovation	- The stronger the ability of innovators to appropriate the benefits of innovation, the lower the likelihood of imitation
		+ The stronger the ability to appropriate the benefits of imitation, the higher the likelihood of imitation
	+ The higher the likelihood that firms will be forced to bear costs of food safety failure, the higher the likelihood of innovation	+ The higher the likelihood that firms will be forced to bear costs of food safety failure, the higher the likelihood of imitation
Size and shape of demand		
Size	+ The larger the market, the stronger the incentive to innovate	+ The larger the market, the stronger the incentive to imitate
Elastic demand	+ The more elastic the demand, the stronger the incentive to invest in process innovations	+ The more elastic the demand, the stronger the incentive to invest in process imitation
Technological opportunity	+ The greater the technological opportunity, the lower the cost of innovation and the greater the incentive to innovate	+ The greater the technological opportunity, the lower the cost of imitation and the greater the incentive to imitate

imitate (adopt a technology developed by someone else in the industry). These three factors influence the costs and benefits of imitation—though not always in the same direction as they influence innovation. Column 3 in table A-1 illustrates how these three factors stimulate or dampen a firm's incentive to imitate.

When innovating firms have strong appropriability mechanisms, the cost of imitation rises, tipping the cost-benefit calculus away from imitation. For example, the cost of imitation is higher when an innovation is patented. Mansfield et al. (1982) found that of 48 firms interviewed, the median estimate of the increase in the cost of imitation due to patents was 11 percent on average. In their survey of American manufacturers, Levin et al. (1987) found that the relative cost of duplicating an innovation was higher for patented than for unpatented process and product innovations. Any innovation appropriability mechanisms that make it more costly for imitators will dampen the extent of imitation.

Potentially large markets and demand elasticities have the same influence on imitation as they have on innovation. Imitators will reap more benefits from investments to duplicate process innovations in large markets with elastic demand.

Technology spillovers from innovating firms reduce the amount of resources imitating firms must spend on R&D activities. Technologies that are easily adaptable to firm-specific characteristics reduce the cost of imitation. Innovative spillovers increase the speed of the diffusion of innovation and increase consumer welfare. Spence (1984) dubs this the efficiency effects of spillovers.

The dynamics of the firm's innovation and imitation incentives reflect constantly changing information regarding the costs and benefits of innovation and imitation—and the extent of appropriability, technological opportunity, and market demand. Firms are constantly adjusting to new information and updating their innovation and imitation strategies. The simple cost-benefit seesaw described in table A-1 is influenced by a stream of new information that can tip the balance without any actual change in the underlying cost-benefit structure.

Market Failure Distorts the Incentives for Food Safety Innovation and Imitation

Though there is no reason to suspect that technological opportunity has been exhausted for food safety innovation, appropriability and market demand seem relatively difficult to establish for food safety. As a result, the incentives for food safety innovation are less than in

industries with large markets and effective mechanisms for appropriating the benefits of innovation. However, weak appropriability may hasten the diffusion of innovation, thus amplifying the consumer benefits of any innovation that does take place. In this section, we examine the logic behind these observations.

Information Asymmetries Erode the Appropriability of Food Safety Innovation

It may be difficult for producers to appropriate the benefits of food safety innovation because improved food safety is a difficult attribute for consumers to detect. For the most part, food safety is a credence attribute. Credence attributes are those that consumers cannot evaluate even when they use or consume the product (Darby and Karni, 1973). Consumers cannot usually determine before purchase, or even after consumption, whether a food was produced with the best or worst safety procedures, or whether a food poses a health risk. For example, consumers are unable to distinguish between raw ground beef contaminated with *E. coli* O157:H7 and uncontaminated ground beef.

Because consumers cannot detect food safety, they may be unwilling to pay a premium for "safer" food. Consumers may worry about fraud and the possibility that some foods marketed as safer products are actually standard or even sub-standard products. In fact, firms producing low-safety foods may have an incentive to market their products as high-safety; they could charge high-safety prices, and because of their cost cutting, have greater profits than high-safety producers. If this incentive were left unchecked, the market would be dominated by low-quality products with little or no product differentiation (Akerlof, 1970). In this case, consumers would be correct in assuming that all products were of low quality unless proved otherwise.

In some cases, food producers themselves may be unaware of the safety characteristics of individual products. For example, poultry producers do not typically have information on whether a specific package of chicken thighs is contaminated with *Salmonella*. Producers do know, however, what safety procedures are maintained in their plants and whether their procedures surpass, meet, or fall below industry standards. As a result, although producers do not have complete information, they have more information than consumers about product safety. Firms with poor safety records may try to take advantage of the fact that consumers lack full information about firms' safety records and market their products as if they had been produced with the best safety technologies.

Producers have developed a number of approaches for overcoming problems associated with marketing credence attributes and for assuring consumers that attributes such as safety actually exist (for a review of this literature, see Golan, Kuchler, and Mitchell, 2000). For food safety and quality, one of the most common approaches is to establish a brand name associated with high standards. Connor and Schiek note the advantages of this strategy (1997, p. 348):

> In consumers' minds the brand names identify the main attributes of the product and are a guarantee of consistent or minimum quality. Brands are preferred by consumers to unbranded products because they reduce the uncertainties concerning product performance, quality, and value associated with food purchases.

Third-party quality verification is another approach used by firms to overcome consumer skepticism regarding credence quality attributes. Third-party entities offer a wide variety of inspection services to verify that a firm's production standards or quality content are as advertised. Third-party certifiers inspect traceability systems to verify the existence of credence process attributes such as organic, fair trade, dolphin-safe, no child labor, and earth-friendly. Third-party certifiers also inspect production facilities and bookkeeping records to verify that firms have adhered to safety standards. Some third-party certifiers provide testing services to verify that pathogen contamination or other safety problems are under control.

A growing number of food manufacturers are insisting on third-party safety certification from their suppliers. Traceability documentation, lab results, and detailed safety inspections are becoming increasingly important in contracts among food processors (Golan et al., 2003). To date, most consumers do not demand this type of information from food suppliers, and firms do not typically supply this information to their consumers. Since this information exists, particularly for high-quality firms, it is puzzling that producers do not use it to advertise their good safety records and appropriate more of the benefits of their safety investments. One reason may be that in advertising their good safety records, and disclosing the poorer safety records of their competitors, firms also disclose general food facts that may frighten consumers. Consumers may not react positively to claims like "our *Salmonella* count is

50 percent less than the leading brand." Firms may decide that though such advertising could differentiate them from poorer quality producers, any overt mention of safety risks could work to their disadvantage and to the disadvantage of the industry as a whole.

In addition, firms may want to avoid specific safety guarantees that could expose them to additional liability. Food safety is not easy to guarantee, particularly in the case of pathogen contamination. Even the most careful producer could experience a safety problem. Deviations from planned procedures, uncertainty regarding input contamination, equipment malfunction, personnel factors, pathogen grow-back, and sampling variability all contribute to the potential for safety breaches (Bisaillon et al., 1997; Bogetoft and Olesen, 2003; Roberts et al., 2001; Sofos et al., 1999).

Firms may also shy away from advertising or establishing other appropriability mechanisms if there is value in some level of anonymity. If appropriability systems increase the probability that a firm will be identified in the case of food safety problems and be exposed to liability, then the firm may have an incentive to forgo appropriating the benefits of a good safety record and to remain anonymous. The benefits of branding, third-party verification, specific quality claims, and other appropriability mechanisms may not outweigh the costs of being more easily linked to a food product in the case of safety problems.

Not only does the ability to remain anonymous dampen the incentive to establish appropriability (and to innovate), it also reduces the threat of punishment in the case of safety lapses, thus further dampening the incentive to innovate. The complex diets of most consumers, the long incubation periods of many foodborne pathogens, incomplete lab analyses of intestinal illnesses, and the fact that the food evidence is usually destroyed (eaten) all reduce the chances of identifying producers of unsafe foods (Buzby et al., 2001). Firms are often able to avoid the negative consequences of safety lapses, including fines, recalls, bad publicity, or litigation because consumers and government regulators are unable to identify the source of foodborne illness. The incentive to invest in food safety is reduced because the probability of detection and punishment in the case of safety failures is less than one.

All in all, the problem of asymmetric information in the market for food safety has the potential to reduce incentives to invest in food safety innovation. The difficulty of advertising and differentiating food on the basis of safety attributes reduces the ability of firms to appropriate the benefits of safety innovation, thereby reducing producers' incentives to invest in safety innovation. Producers' incentives to invest to overcome appropriability constraints are in turn damped by the fact that anonymity is valuable in the case of food safety problems. As a result, the amount of food safety and food safety innovation supplied by the market is likely to be lower than the socially optimal amount.

The Nature of the Product May Dampen Demand for Food Safety

Consumers also play a role in slowing the development of markets for food safety and in dampening incentives to invest in food safety. Skeptical, discerning consumers are not the norm when it comes to food safety attributes. Most consumers are unaware of the specifics of food production—and many may prefer to stay that way. For example, Kuchler (2001) argues that consumers do not really want to know the content of most processed meat and, as a result, labels indicating that a product contains "meat" are preferable to more specific labels indicating what meat actually is, such as the official "Muscle tissue of cattle, sheep, swine, goats, or equines which is skeletal or found in the tongue, diaphragm, heart, or esophagus with or without accompanying or overlaying fat, bone, skin, sinew, nerve, or blood vessel which are not separated during dressing" (USDA, FSIS, no date).

Whether they do not want to know or just do not have the time to learn, consumers do not know very much about how food is produced or about food safety. In the United States, both marketplace behavior and survey results indicate that most consumers are not very knowledgeable about food content or production practices. Throughout the 1990s, surveys found that only 30 to 40 percent of consumers in the United States were aware of the use of biotechnology in food production and most were unaware of general food production techniques.

The low level of consumer knowledge about food safety makes it difficult to gauge the size and depth of the market for food safety. The low level of knowledge may also contribute to the susceptibility of this market to large perturbations after foodborne illness outbreaks: well-publicized outbreaks may be many consumers' sole source of safety information. In fact, dramatic and highly publicized outbreaks have often driven sharp increases in demand for

safety, at least in the short run. In Europe, a number of high-profile scares, including those involving Bovine Spongiform Encephalopathy (BSE or mad cow disease) and dioxin-contaminated feed have triggered increased demand for food safety. In the United States, the 1993 outbreak of *E. coli* O157:H7 in Jack-in-the-Box hamburgers led to a dramatic decrease in demand and the company lost around $160 million in the 18 months following the outbreak (Roberts et al., 1997).

If the size and intensity of consumer demand have the same impact on food safety innovation as they do on innovation in other industries, then the rather nebulous and episodic demand for food safety probably dampens incentives to invest in food safety innovation.

Asymmetric Information Helps Spur Imitation and Technological Spillover

Asymmetric information problems may ultimately amplify the benefits of food safety innovations by providing innovating firms with an incentive to share new technologies with their competitors. A food safety problem in one firm or one segment of an industry has the potential to discredit a whole industry because consumers cannot distinguish safe and unsafe product and producers. For example, the BSE outbreak in the United Kingdom dampened beef markets around the world, not just markets where producers used feed containing mammalian protein. As a result, safe producers have an incentive to try to raise the safety level of the whole industry. The desire of safe firms to protect themselves from negative publicity means that spillovers could be large in food safety. This observation may help explain why the American Meat Institute, the National Chicken Council, the National Cattlemen's Associations, and other industry groups support food safety research activities and information dissemination.

The same incentive does not exist in other markets. For example, faulty brakes on one brand of cars do not hurt business for other brands of cars. A car brand with an innovative new braking system has no incentive to share the discovery with its competitors in order to bolster the reputation of the industry. However, because of asymmetric information problems in markets for meat safety, massive recalls of hamburger, for example, shake consumer confidence in the whole industry. Hamburger-borne disease outbreaks hurt everyone in the industry, and innovation to reduce such outbreaks helps everyone in the industry—including the innovating firm. In the hamburger industry, and many other food industries, negative spillovers provide an added incentive to innovate and disseminate innovation.

Firms also have an incentive to share new technologies with their competitors and with government regulators to influence the standard of care in the industry. In some cases, standards of care that are difficult to meet can help establish a barrier that benefits the firms that first adopt such standards. First adopters gain larger market shares (and maybe market power) if the expense of new technologies forces some producers out of business. Even if all firms eventually adopt the technology, first adopters will benefit from limited competition during the period when their competitors are installing the new technologies. Such benefits may help explain why the large meat and poultry slaughter and processing plants generally have supported stricter food safety regulation.

Imitative spillovers of innovations are prevalent in the food processing industry. Levin et al. (1987), in their survey of American firms, report that many in the food processing industry found patents ineffective because they often did not withstand legal challenges. Eleven of 130 industries in the Levin et al. survey, all from the food processing and metalworking sectors, reported that no mechanism of appropriating the returns from product innovation was even moderately effective.