The Cost of Quality in the Meat Industry: Implications for HACCP Regulation

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This paper develops a framework for measuring the plant-level cost of quality regulations, based on models of the production of quality-differentiated products. This framework emphasizes the potential importance of the impacts of regulations on both variable and fixed costs of production. Evidence on the potential impacts of food safety regulation on variable costs of production is presented from a recent study of the meat and poultry industry.

The Regulatory Impact Assessment of USDA's new food safety regulations, including mandatory HACCP, provided an upper-bound estimate of the possible benefits of the regulations that far exceeded the estimated cost. However, the USDA's cost estimate was not comparable to the upper-bound estimate of the benefits. As also noted by Belzer (1998), the regulatory impact assessment assumed that the HACCP regulations would not affect the productivity of meat and poultry plants or their variable cost of production. Utilizing the framework developed in the first part of this paper, econometric estimates of variable cost functions for meat packing plants and poultry slaughter and processing plants are utilized to assess the potential costs of food safety regulations such as mandatory HACCP. These estimated cost functions show that variable cost of production is increasing in product quality. Assuming the regulations are 20 percent effective

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and that health risk reduction is proportional to pathogen reduction, the upper-bound estimate of benefits is $736 million annually. The upper-bound estimate of the costs of the regulations derived from econometric cost functions, assuming 20 percent effectiveness, is $6.7 billion (1995 dollars). Thus, the upper-bound estimate of the costs substantially exceeds the upper bound estimate of the benefits.

The costs of food safety regulation include the industry's cost of compliance, borne by both industry and the consumers of their products, as well as administrative costs borne by taxpayers and the deadweight loss associated with taxation. The focus here is on the plant-level costs of compliance with regulations and their implications for regulatory impact assessment.

Product Quality and Production Structure

Analysis of the costs of food safety regulation begins at the plant level. For convenience, this discussion makes the simplifying assumption that each firm operates a single plant. For analysis of market structure and competition, the distinction between plants and firms and issues such as economies of scale and scope need to be given further consideration (Panzar 1989). This discussion focuses on the costs of statutory regulation taking the form of either performance standards or process standards. Analysis of other regulatory approaches, such as liability or product certification, involve considerations beyond the structure of the firm's production technology that are not discussed here.

Analysis of food safety requires consideration of production models that allow for quality-differentiated products (Antle 1998a). To illustrate, consider a firm operating a single plant and producing a single product, y, with quality q. For modeling purposes, quality is defined as a scalar variable, and interpreted as an index of multiple quality attributes. Wholesale markets for meat products differentiate several quality dimensions for which a buyer may be willing to pay a price premium: taste, as represented by USDA grades for red meat; safety, defined as the absence of pathogens and other hazards; wholesomeness and freshness, as related to absence of bacteria that cause spoilage and limit shelf life of fresh products; and other miscellaneous characteristics such as quality of packaging and reliability of supply.

Define the firm's production inputs as the vector $\mathbf{x}$ and capital stock k. The general form of the firm's production function is $f(y,q,\mathbf{x},k) = 0$, where $f(\bullet)$ satisfies the standard properties of multiple output technologies (Chambers 1988). In this form, quality can be interpreted as a second output of the production process, and the literature on multiple output technologies can be utilized. Two important properties of multi-product technologies are input-output separability and nonjointness in inputs. Input-output separability holds if and only if the production function can be written $f^1(y,q) = f^2(\mathbf{x},k)$. In effect, this property implies that the quantity of output y and output quality q can be aggregated using the function $f^1(y,q)$. Such aggregation is not useful in an analysis where the objective is to explicitly account for product quality.

Nonjointness of inputs implies that separate production functions of the form $y = f^y(\mathbf{x}^y,k^y)$ and $q = f^q(\mathbf{x}^q,k^q)$ can be defined. Some aspects of quality control, such as record keeping and product testing, are separate from the production process. Also, certain food safety processes, such as food irradiation, may operate separately from the rest of the production process. However, many aspects of quality control, such as temperature controls, cleaning of equipment, and removal of contaminated product, are integrated into the production process and may affect the overall productivity of the process (e.g., by affecting the number of hours the plant can operate and the speed at which slaughter lines can be operated). Therefore, the representation of production technologies for quality-differentiated products is likely to take the form of a multi-output process that is joint in inputs involved in the production process and in some aspects of quality control, but also may be nonjoint in other quality control inputs.

While multi-output production technologies can be utilized in the primal form, for both analysis and estimation purposes it is typically more convenient to use dual cost or profit representations of multiple-output technologies. The general nonseparable, joint representation of the variable or restricted cost function corresponding to the production function $f(y,q,\mathbf{x},k) = 0$ takes the form $vc(y,q,\mathbf{w},k)$ where $\mathbf{w}$ is a vector of prices corresponding to the input vector $\mathbf{x}$. In the case where production is nonjoint in inputs and there are distinct production functions, it then follows that dual cost functions exist of the form $vc^y(y,\mathbf{w},k)$ and $vc^q(q,\mathbf{w},k)$ (Hall, 1973). As a generalization of this conventional nonjoint-in-inputs model, the preceding discussion suggests that in the case of quality-differentiated food products, the cost function may generally take the form

$$c(y,q,\mathbf{w},k,\alpha,\beta,\gamma) = vc(y,q,\mathbf{w},k,\alpha) + qc(q,\mathbf{w},k,\beta) + fc(k,\gamma) \tag{1}$$

where total cost $c(\bullet)$ is composed of a component of variable cost $vc(\bullet)$ that is joint in conventional production inputs and some quality control inputs, a component of variable cost $qc(\bullet)$ that is nonjoint in conventional inputs and certain quality control inputs (thus it is independent of y but depends on q), and a conventional fixed cost component $fc(k)$ that is independent of both output and quality. Here α,β and γ are parameters of the respective components of the cost function.

Measuring Costs of Performance Standards and Process Design Standards

Statutory regulation takes two basic forms, performance standards and process design standards. Following Antle (1998c), this section uses the results of the preceding section to show how the costs of these two types of regulation can be measured.

Performance standards impose the requirement that a firm must achieve a level of product quality, q_g, but do not specify the technology that the firm must use to achieve the standard. In the simplest case, a plant can efficiently achieve the higher standard with the technology that was in use before the standard was imposed, where the technology is defined in terms of the cost function parameters and the capital stock. Letting the level of product quality supplied before the regulation be q_0, the imposition of the performance standard $q_g > q_0$ results in an increase in the cost of production equal to

(2) $\Delta c(y,q_0,q_g,\mathbf{w},k,\alpha,\beta,\gamma) = \Delta vc(y,q_0,q_g,\mathbf{w},k,\alpha) + \Delta qc(q_0,q_g,\mathbf{w},k,\beta)$.

where

$$\Delta vc(y,q_0,q_g,\mathbf{w},k,\alpha) \equiv vc(y,q_g,\mathbf{w},k,\alpha) - vc(y,q_0,\mathbf{w},k,\alpha)$$

$$\Delta qc(q_0,q_g,\mathbf{w},k,\beta) \equiv qc(q_g,\mathbf{w},k,\beta) - qc(q_0,\mathbf{w},k,\beta).$$

In implementing a performance standard, a firm may choose to modify its production process to achieve the mandated quality standard more efficiently, even though it is not required to do so in the regulations. Modifications of the existing plant and equipment or other operating characteristics of the plant would result in a change in the parameters of the cost function. It may also be necessary to invest in new plant and equipment, changing the firm’s capital stock. Let the firm’s modified production process under the performance standard be represented by the parameters α_p, β_p, and γ_p and the capital stock k_p. The change in cost of production induced by compliance with the performance standard is then:

(3) $$\Delta c(y,q_0,q_g,\mathbf{w},k_0,k_p,\alpha_0,\beta_0,\gamma_0,\alpha_p,\beta_p,\gamma_p) =$$

$$\Delta vc(y,q_0,q_g,\mathbf{w},k_0,k_p,\alpha_0,\alpha_p) + \Delta qc(q_0,q_g,\mathbf{w},k_0,k_p,\beta_0,\beta_p) + \Delta fc(k_0,k_p,\gamma_0,\gamma_p),$$

where

$$\Delta vc(y,q_0,q_g,\mathbf{w},k_0,k_p,\alpha_0,\alpha_p) \equiv vc(y,q_g,\mathbf{w},k_p,\alpha_p) - vc(y,q_0,\mathbf{w},k_0,\alpha_0)$$

$$\Delta qc(q_0,q_g,\mathbf{w},k_0,k_p,\beta_0,\beta_p) \equiv qc(q_g,\mathbf{w},k_p,\beta_p) - qc(q_0,\mathbf{w},k_0,\beta_0)$$

$$\Delta fc(k_0,k_p,\gamma_0,\gamma_p) \equiv fc(k_p,\gamma_p) - fc(k_0,\gamma_0).$$

While conceptually straightforward, these alternative cases have significantly different data requirements for estimation. In the simple case (2) where the technology is not changed to comply with a performance standard, data from the time period before the regulation is imposed can be used to estimate the cost function, and this cost function can then be used to estimate the costs of the performance standard (assuming that the technology has not changed during that time interval for other reasons not related to the regulation). However, in the case (3) where the technology changes in response to the regulation, both pre- and post-regulation data are needed to estimate the cost functions and the capital stocks in order to make accurate estimates of the cost of the regulation.

Clearly, the problem posed by case (3) for conducting RIAs is that the cost estimates need to be made *ex ante* before post-regulation data are available. A more feasible strategy is to assume that the capital stock is changed but the parameters of the process are not changed. In that case, the regulatory cost is:

(4) $$\Delta c(y,q_0,q_g,\mathbf{w},k_0,k_p,\alpha,\beta,\gamma) = \Delta vc(y,q_0,q_g,\mathbf{w},k_0,k_p,\alpha) + \Delta qc(q_0,q_g,\mathbf{w},k_0,k_p,\beta) + \Delta fc(k_0,k_p,\gamma),$$

In this case, regulatory costs can be estimated using the pre-regulation cost function with the addition of information about the change in the capital stock. If firms do in fact modify their production processes so as to be more efficient, then (4) will provide an upper bound approximation of (3). This observation also suggests that a useful research topic would be to obtain both *ex ante* and *ex post* data in order to assess the difference between (3) and (4) in case studies.

A strict process design standard specifies the technology that a firm must use, without specifying the outcome that must be achieved as in a performance standard. A design standard will generally require firms to modify their plant and equipment and the production process to meet the government standards. The mandated technology is represented by the capital stock k_g and the cost function parameters α_g, β_g ,and γ_g . However, in the case of the process design standard, the new level of product quality that is achieved, q_1, is not specified in the regulation and not known *ex ante*. Following equations (2) and (3), the cost of a process design standard is given by

$$(5) \qquad \Delta c(y,q_0,q_1,\mathbf{w},k_0,k_g,\alpha_0,\beta_0,\gamma_0,\alpha_g,\beta_g,\gamma_g) = \Delta vc(y,q_0,q_1,\mathbf{w},k_0,k_g,\alpha_0,\alpha_g) + \Delta qc(q_0,q_1,\mathbf{w},k_0,k_g,\beta_0,\beta_g) + \Delta fc(k_0,k_g,\gamma_0,\gamma_g).$$

While they appear to be similar, there are important differences between the cost of a performance standard (3) and a process design standard (5). First, the performance standard establishes a level of quality or safety q_g that must be achieved by every plant. In contrast, the level of safety q_1 achieved by a process design standard will vary across plants because each plant is actually designed and operated differently, in spite of the process standard. Second, because the performance standard allows plant managers to tailor quality control to fit their particular plant's design, there is a presumption that the cost of the performance standard will be less than the cost of the process standard in achieving a given level of safety (Antle, 1995). This hypothesis could, in principle, be tested with appropriate data and methods using the relationships identified here.

Regulations may also combine elements of both performance and process design standards, as the in the case of the U.S. Department of Agriculture's recently implemented meat inspection regulations that combine a mandatory quality-control system with performance standards for certain microbial contaminants, giving a regulatory cost measured as:

$$\Delta c(y,q_0,q_p,\mathbf{w},k_0,k_g,\alpha_0,\beta_0,\gamma_0,\alpha_g,\beta_g,\gamma_g) = \Delta vc(y,q_0,q_p,\mathbf{w},k_0,k_g,\alpha_0,\alpha_g) + \Delta qc(q_0,q_p,\mathbf{w},k_0,k_g,\beta_0,\beta_g) + \Delta fc(k_0,k_g,\gamma_0,\gamma_g). \tag{6}$$

Finally, recall that for simplicity of the presentation, quality (or safety) are treated here as a single dimension. In many cases there will be multiple dimensions of quality, including one or more safety attributes (such as presence of multiple pathogens). Some of these safety dimensions may be specified in performance standards and others may be addressed through design standards, or not addressed. The recent pathogen reduction and HACCP regulations implemented by USDA provide an example of this mixed approach to food safety regulation.

The Cost of Quality in the Meat and Poultry Industries: Evidence from Estimates of Variable Cost Functions

The preceding section shows that the impacts of regulation on plant-level cost of production can be measured as changes in variable cost of production that occur in the production process, changes in variable quality control inputs that are independent of the production process, and changes in fixed costs. This section reviews recently developed methods for estimating the first of these components of cost, those associated with changes in the variable cost of production, and summarizes the findings of a recent study of the meat and poultry industry (Antle, 1998b).

To empirically implement estimation of the variable cost functions $vc(y,q,\mathbf{w},k,\alpha)$ and $qc(q,\mathbf{w},k,\beta)$, conventional econometric procedures can be utilized if quality is observable. The key problem is that data on product quality (i.e., the rate of occurrence of meat products contaminated with microbes) is not usually available. Assuming that the firm is a price-setting monopolist, Gertler and Waldman (1992) developed an econometric approach to estimation of the cost function with unobserved quality. This approach uses demand variables as instruments for the quality variable in the cost function. This model requires that each firm or plant face different demand conditions so that there is variation in demand variables across observations to identify quality parameters in the cost function.

Antle (1998b) observes that a monopolistic model is not suitable for analysis of cost of production in the meat packing and food processing industry where product markets are competitive. Antle combines Rosen's (1974) model of a competitive industry producing quality differentiated products with Gertler and Waldman's model of a quality-adjusted cost function, and shows that the observed market price for output can be used as an instrument to identify quality.

Cost functions were estimated using data from the Census of Manufactures for slaughter and processing plants producing beef, pork and poultry (Table 1). Most of the industry's output is produced by larger plants (a large plant is defined here as producing more than 100 million pounds of product annually). The Census of Manufactures data also show that the variable costs of these plants are dominated by the cost of animal inputs, and that variable cost represents 90 percent or more of total cost (more than 95 percent in the case of large plants). This is an important fact for analysis of the costs of regulation. It implies that if indeed regulation has an impact on both variable and fixed costs of production, the impact on variable cost is likely to be most significant simply because variable costs are such a large share of total cost of production.[2]

Table 1. Plant Numbers and Production By Plant Size, 1992 (Production in billions of pounds)

	Small		Large		Total	
	Plants	Production	Plants	Production	Plants	Production
Beef	52 (54.7)	2.02 (10.2)	46 (48.4)	17.83 (89.8)	95	19.85
Pork	44 (57.1)	0.87 (7.3)	33 (42.9)	11.05 (92.7)	77	11.92
Poultry	87 (43.1)	4.13 (17.5)	115 (56.9)	19.44 (82.5)	202	23.57

Note: Small plants defined as production less than 100 million lbs/year.
Large plants defined as production greater than or equal to 100 million lbs/year.
Percentages in parentheses.
Source: Antle (1998b).

Translog cost functions were estimated for the small and large plant groups with 1987 and 1992 data for beef, pork and poultry plants. The hypothesis that variable cost is not a

[2]Some commenters have questioned this conclusion by arguing that *processing* cost is not a large share of total cost, and that only processing cost is affected by the regulations. To see why a reduction in processing efficiency affects overall efficiency, let variable cost be $vc(y,q,w,k) = vc_p(q,w_L,k)\bullet vc_m(w_m)\bullet y$ where vc_p is the unit processing cost, w_L is the wage rate of processing labor, vc_m is the unit variable cost of animal inputs, and w_m is the price of meat inputs. Even though processing cost may be separable from meat input cost, as in this example, the multiplicative property of the cost function means that if regulations reduce processing efficiency and, thus, unit processing cost increases by X percent, total variable cost increases by X percent.

function of product quality was overwhelmingly rejected for all plant size groups and for beef, pork and poultry plants. The estimated cost functions show that variable cost of production is an increasing function of product quality, as hypothesized. Table 2 presents the elasticities of cost with respect to quality derived from translog cost function models. The translog models show a positive elasticity of cost with respect to quality, as predicted by economic theory.

Table 2. Cost Elasticities for Quality Derived from Translog Quality-Adjusted Cost Functions for Small and Large Plants for Beef, Pork, and Poultry Slaughter and Processing

	Beef		Pork		Poultry	
	Small	Large	Small	Large	Small	Large
Quality Elasticity	1.14	0.77	0.47	0.63	0.62	0.52

Source: Antle (1998b).

Implications for Costs of Mandatory HACCP

In July 1996 the Food Safety and Inspection Service (FSIS) announced new regulations for all meat and poultry plants. All slaughter and processing plants are now required to adopt the system of process controls known as Hazard Analysis and Critical Control Points (HACCP). To verify that HACCP systems are effective in reducing bacterial contamination, pathogen reduction performance standards are being established for *Salmonella*, and slaughter plants are required to conduct microbial testing for generic *E. coli* to verify that their process control systems are working as intended to prevent fecal contamination, the primary avenue of bacterial contamination. FSIS is also requiring plants to adopt and follow written standard operating procedures for sanitation to reduce the likelihood that harmful bacteria will contaminate finished products.

The regulatory impact assessments conducted by FDA and USDA utilized various parts of the scientific literature on food-borne illness to estimate the potential benefits of reducing such risks (see reviews of the literature in Council for Agricultural Science and Technology, 1994, and Caswell, 1995). On the benefits side several key assumptions were made, including: (1) the number of unreported illnesses and deaths attributable to food pathogens; (2) the effectiveness of the regulations in reducing pathogens in meat products; and (3) a proportional relationship between pathogens in meat products and frequency of food borne illness. A great deal of scientific uncertainty surrounds these assumptions. There is some scientific basis for the estimation of unreported illnesses and deaths (Council for Agricultural Science and Technology), although those numbers are controversial (Wilson). On the effectiveness of the regulations, FSIS stated, “FSIS recognizes that the actual effectiveness of the final requirements in reducing pathogens is unknown...” (FSIS, 1996, p. 38968). In the regulatory impact assessment of the final rule, FSIS utilized a range of effectiveness from 10 to 100 percent. On the issue of proportionality between pathogen prevalence and food borne illness, FSIS stated in the Regulatory Impact Assessment, “FSIS has not viewed proportional reduction as a risk model that would have important underlying assumptions that merit discussion or explanation. For a mathematical expression to be a risk model, it must have some basis or credence in the scientific community. That is not the case here. FSIS has acknowledged that very little is known about the relationship between pathogen levels at the manufacturing stage and dose, i.e., the level of pathogens consumed.” (FSIS, 1996, pp. 38945-38946). It can be concluded that, because of the scientific uncertainty surrounding the effectiveness of the regulations, studies of the costs of foodborne disease can only provide an approximate upper bound on the potential benefits of food safety regulation. That is, they provide a measure of the potential benefits that would be realized if regulations were to eliminate *all* risk of foodborne illness.

The FSIS Regulatory Impact Assessment also made certain assumptions in estimating costs. The FSIS analysis of the costs of the new regulations was based on an accounting methodology that assumed that the costs of the regulations would be comprised of quality control activities, such as record keeping and product testing, and some process modifications assumed to be necessary to meet the regulatory requirements. However, the analysis assumed that the implementation of the new regulations would have no effect on the overall operating efficiency of the production process and thus would not affect the variable cost of production. Curiously, FSIS justified this assumption by arguing that if any additional costs were incurred in meeting the new regulations, they should not be attributed to the regulatory process because the new regulations are simply "...a more effective way of assuring that establishments meet "already established health and safety related requirements." (FSIS, 1996, p. 38979). Under this assumption, the FSIS found that the recurring cost of the regulations would be on the order of $100 million per year (in 1995 dollars), or less than 0.1 cent per pound of meat product (Crutchfield *et al.*).

The inadequacy of the cost data and analysis did not go unnoticed by other economists. According to Belzer (1998, p. 20), "... the analysis contains several material errors in its cost assessment that severely understate the likely costs of the rule. First, the estimated cost of required SSOPs (standard sanitary operating procedures), HACCP (hazard analysis critical control points) plans, and generic *E. coli* testing includes only the cost of writing the plans themselves, training current employees, and performing the microbiological tests. *The costs associated with the operational changes necessary to comply with SSOPs and HACCP plans were not included."* (Belzer, 1998, p. 20, emphasis added). Belzer also observes, "...the estimated cost of preparing HACCP plans in the analysis is unreliable. This estimate was based on a sample of nine establishments who volunteered to participate in an agency study and are not representative of the several thousand establishments regulated under this rule. Statistical inferences from even a random sample of nine are problematic, but they are obviously illegitimate from a convenience sample of nine volunteers."

The key problem in estimating the cost of food safety or other quality regulations is that quality data, such as the prevalence of pathogens in meat products, are not available at the plant level. The principal contribution of the econometric approach described above is that it utilizes economic information, i.e., prices, to identify the relationship between quality and cost of production. This relationship provides the basis to estimate the impacts of quality regulations on variable cost of production, what was referred to in the above quote of Belzer as the costs of operational changes needed to comply with regulations. The potential importance of this component of the regulatory cost is highlighted by the fact that most meat and poultry products in the United States are produced by large scale, highly efficient plants whose efficiency is directly related to factors such as the speed of slaughter lines. Regulations that slow line speeds will reduce the overall operating efficiency of a plant and raise average variable cost of production. Variable cost of production represents over 90 percent of total costs in most meat and poultry slaughter and processing plants in the United States, according to the data from the Census of Manufactures.

To estimate costs, FSIS utilized an accounting methodology wherein the cost of each component of the regulation (e.g., implementation of standard operating procedures, training personnel in quality control methods, and keeping records), is estimated for representative small and large plants. These plant-level cost estimates were then used to estimate the industry-wide costs of the regulations. From an economic perspective, this accounting approach to cost estimation has a significant shortcoming. In the application of the accounting approach, the costs of producing a safer product are assumed to be variable costs independent of the production process, or fixed costs. The costs of making certain process modifications are estimated, but the effect of the regulations on the overall operating efficiency of the process is not considered, and thus is implicitly assumed to be zero. In terms of the analysis of the costs of regulation presented earlier, this is equivalent to assuming that the Δvc terms in equations (2) through (6) are equal to zero. This assumption contradicts the findings discussed in the preceding section, where it was found that variable cost of production in beef, pork and poultry slaughter and processing plants is a function of product quality. Because variable cost is a large share of total cost, it follows that quality regulations, such as food safety regulations, can result in substantial increases in the cost of production, as will now be demonstrated in the case of meat and poultry plants.

As noted in the first section of this paper, wholesale meat markets recognize taste, safety, wholesomeness, and other miscellaneous quality attributes for which buyers may be willing to pay a price premium. Thus, the quality component of the cost function estimated in the preceding section can be interpreted as reflecting some combination of these quality attributes. If data were available on these quality attributes, it would be possible to estimate a hedonic relationship that would indicate the contribution of each of these attributes to overall quality and product price. Lacking such data, the analysis of regulatory cost can proceed only by assuming that some share of the cost of production associated with quality improvements is attributable to safety improvement. The upper limit on the share of quality attributable to safety is obviously 100 percent. Thus, by interpreting quality as equivalent to safety, the cost functions estimated in the preceding section can be interpreted as providing an upper bound on the potential costs of quality improvements associated with food safety regulations.

According to the definitions given in the first section of this paper, the USDA's mandatory HACCP regulations and standard operating procedures are process design standards because they specify the process to be used, not the safety attributes of the end products. But the regulations also involve performance standards for *Salmonella* and generic *E. coli*. Following the discussion above (see equation 6), the best approach to estimate the costs of implementing combined design and performance standards is to estimate the cost function before and after the implementation of the regulation, and then utilize these pre- and post-regulation cost functions to calculate the increase in production costs, holding constant output and factor prices. Clearly, this approach is not possible before regulations have been implemented. For *ex ante* analysis of regulations, the alternative proposed here is to approximate the cost of the process design standard with the cost of an equivalent performance standard based on the pre-regulation technology. This amounts to using equation (2) in conjunction with an estimate of how effective the regulations will be in improving product safety (i.e., an estimate of the performance standard's effectiveness represented by a value of q_g).

Equation (2) is a special case of equation (3), wherein the technology (represented by the parameters and the capital stock) do not change. Note that the term involving changes in fixed costs is equal to zero by the assumption that the capital stock is not changed. The $\Delta qv(\bullet)$ term can be interpreted as the costs of quality control estimated by FSIS in its regulatory impact assessment. These costs of quality control are "fixed" in the sense that they do not vary with the rate of output, but as discussed above, in the interpretation of the multi-output cost function these costs vary with the level of quality produced, and so are variable costs that are non-joint with output. The term $\Delta vc(\bullet)$ is the change in variable costs of production associated with changes in input use (labor and materials) necessitated by the imposition of the higher quality standard.

As noted above, in the regulatory impact assessment of the final rule, the FSIS utilized a range of effectiveness from 10 to 100 percent because of the lack of scientific data to indicate the likely effectiveness of the regulations. The only attempt to assess the effectiveness of these regulations *ex ante* is the study by Knutson *et al.* (1995). In that study, a group of experts in food microbiology estimated that the proposed regulations would be likely to be 20 percent effective.

To estimate the cost of the new regulations, the level of product safety that was achieved before the regulations were imposed also must be estimated. As explained above, the quality-adjusted cost function can be used to provide an upper bound on the costs of safety regulations by interpreting the units of quality in the econometric model as units of safety. Because safety is unobserved, the units of safety and its base level are not defined by data contained in the model. Nevertheless, we know that prior to the new regulations, some degree of safety between zero and 100 percent was being achieved by plants in the industry. Let the level of safety prior to the new regulations be *S* , and interpret this number as a percentage so that $0 \leq S \leq 100$. It follows that if the regulations are *e* percent effective in reducing pathogens, the observed level of safety is increased by $e(100 - S)$ percentage points or by $e(100 - S)/S$ percent. Extensive data have been collected about the prevalence of food pathogens (Council for Agricultural Science and Technology, 1994). Surveys of raw meats and poultry show that prevalence of various pathogens ranges from zero to 100 percent, with many in the range of 10 to 50 percent. Therefore, in this analysis, the regulatory costs are estimated assuming the level of safety prior to the new regulations ranged from 50 to 90 percent.

Based on equation (2), the annual change in plant-level variable costs from implementing a regulation that is *e* percent effective, starting from a safety level of *S* percent is calculated as:

$$(7) \qquad \Delta vc(e,S) = (N_{small} \cdot VC_{small} \cdot E_{small} + N_{large} \cdot VC_{large} \cdot E_{large}) \cdot e(100\text{-}S)/S$$

where

e = effectiveness of the regulations (percent reduction in pathogens)

S = percent degree of safety prior to imposition of the regulations

E_i = elasticity of cost with respect to safety for i=small, large plants

N_i = number of plants for i=small, large groups

VC_i = variable cost for i=small, large plants

According to the calculations made by FSIS, if the regulations are 20 percent effective the annual benefits would be in the range of $198 million to $736 million (in 1995 dollars). The annual quality control costs of the regulations were estimated to be about $100 million. Using equation (7), the costs of a 5, 20, and 35 percent improvement in safety were estimated for prior safety levels of *S* = 50, 70 and 90 percent. Table 3 shows that the upper-bound estimate of the increase in annual total variable cost for beef, pork and poultry plants, assuming regulations are 20% effective, ranges from $743 million to $6.7 billion. These data demonstrate that the costs of food safety regulations associated with increases in variable costs of production may be substantially greater than the quality-control costs estimated by FSIS. The data in Table 3 show that the upper-bound estimate of the costs of the new regulations exceed the upper-bound estimate of the benefits. It is important to note that while the plants in this sample represent most of the meat and poultry produced in the United States, there are many other establishments covered by the regulations (such as small meat processing establishments) that are not included in the Census of Manufactures data utilized here. Thus, the costs in Table 3 are an underestimate of the possible total industry cost of the regulations.

Table 3. Upper-Bound Estimate of Annual Increase in Variable Cost of Beef, Pork and Poultry Slaughter and Processing Plants for Alternative Levels of Base Safety and Regulatory Effectiveness (Industry Cost in Million $1995)

	Effectiveness of Regulation (percent increase in safety)		
Base Safety (percent)	5	20	35
50	1,673	6,690	11,708
70	558	2,230	3903
90	186	743	1300

Source: based on data in Antle (1998b).

The FSIS estimates imply that regulatory costs are less than 0.1 cent per pound, regardless of the effectiveness of the regulations (Crutchfield *et al*., 1997). Table 4 presents the data from Table 3 for the case of 20 percent effectiveness, translated into costs per pound. These data show that the cost per pound ranges from 0.6 cents per pound for pork and poultry with 90 percent base safety, to as high as 24 cents per pound for small beef plants and 50 percent base safety.

Table 4. Estimated Upper-Bound Increase in Variable Costs Per Pound of Production for a 20% Improvement in Safety ($1995)

	Beef		Pork		Poultry	
	Small	Large	Small	Large	Small	Large
Base Safety = 50%	0.237	0.211	0.082	0.088	0.078	0.055
Base Safety = 70%	0.079	0.070	0.027	0.026	0.026	0.108
Base Safety = 90%	0.026	0.023	0.009	0.010	0.009	0.006

Note: Base safety is the level of product safety prior to the 20% improvement in safety.
Source: Antle (1998b).

The data in Table 4 show that the costs are generally higher for small beef and poultry plants than large plants, but this difference does not appear to hold for pork plants. The data in Table 4 also show that beef plants are likely to experience a much larger increase in cost per pound than either pork or poultry plants. These findings have several potentially significant implications for the meat industry when considered in the context of the structural changes that have been occurring in the industry. First, the greater cost impact on smaller plants could put them at a competitive disadvantage relative to large plants. The regulatory cost difference between small and large plants also would depend on whether the products of small plants are more or less safe than the products of large plants. If, for example, small plants produce safer products than large plants, and if the regulations would require all plants to achieve the same level of safety, then small plants would need to increase their safety by a smaller amount than large plants, and thus would be affected relatively less than large plants. The converse obviously would be true if small plants produce products that are less safe than large plants.

A second implication of the data in Table 4 is the higher regulatory cost for beef as compared to pork or poultry plants. This differential would appear likely to further accentuate the market price differential between beef and pork or poultry, and thus further encourage the observed trend in consumption away from beef towards pork and poultry (Brester, Schroeder and Mintert, 1997). The significance of this differential depends on both the effectiveness of the regulations and the degree of safety attained by the industry prior to regulation.

Conclusions

This paper begins with a discussion of the structure of cost functions for meat plants producing quality-differentiated products, focusing on the jointness properties of conventional inputs and quality control inputs. This structure is used to explore how the plant-level costs of performance standards and design standards can be measured, including difficulties in *ex ante* assessment when only parameters of the pre-regulation technologies are known. A topic identified for future research is to compare the accuracy of *ex ante* estimates of the costs of regulation with the observed *ex post* costs of regulation, to determine whether how reliable *ex ante* estimates are for future regulatory assessments.

These results are used to investigate implications for the costs of the HACCP and related regulations being implemented by USDA, by using the model of a performance standard to estimate the implied cost of achieving a higher quality product. Estimates of variable cost functions for beef and pork packing plants and for poultry slaughter and processing plants in the

United States show that variable costs of production are an increasing function of product quality, and variable costs of production are a large share of total cost. Noting that quality comprises several product attributes including safety, these cost functions can be used to provide an upper bound on the cost associated with raising product quality through food safety regulations. The analysis shows that safety regulations that significantly affect the efficiency of the production process can significantly raise the cost of production. These costs were not included in the FSIS regulatory impact assessment of the new food safety regulations. When it is assumed that the cost of production will increase with the effectiveness of the regulations, the analysis indicates that the upper-bound estimate of the costs of the regulations could exceed the upper-bound estimate of the benefits contained in the FSIS regulatory impact assessment. This conclusion is reinforced by the fact that the data used to estimate these costs represent most of the meat packing and poultry slaughter and processing industry, but do not cover other establishments beyond the packing and processing stage that are also affected by the regulations.

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