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Objective Analysis
for Informed
Decision Making

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Abstract

Using an accounting methodology, the U.S. Department of Agriculture's estimates of the costs of new food safety regulations in the meat industry indicate that the benefits will exceed the costs of the regulations by hundreds of millions or billions of dollars annually. The purpose of this paper is to develop an econometric approach to the estimation of the plant-level costs of quality regulations, such as recent food safety regulations, that can be implemented with publically available data. The theoretical and empirical models proposed in this study are based on the integration of Rosen's (1974) model of a competitive industry producing quality-differentiated products with Gertler and Waldman's (1992) model of a quality-adjusted cost function. Using plant-level data available from the Census of Manufactures, quality-adjusted cost functions are estimated for beef, pork and poultry slaughter and processing plants. These cost functions are used to assess the potential costs of the new food safety regulations being imposed on the industry. Statistical tests strongly reject the assumption made in the USDA study that variable cost of production is independent of product safety, showing that food safety regulations affect the overall operating efficiency of meat slaughter and processing plants. The econometric models estimated in this study indicate that the plant-level costs of the regulations, assuming they are 20 percent effective, are likely to be in the range of $750 million to $6.8 billion (1995 dollars) – or more than one order of magnitude higher than the cost estimates made by USDA. Thus, the findings of this study cast doubt on the proposition that there is a virtual free lunch in food safety regulation in the meat industry, and show that the costs of these regulations could well exceed estimated benefits.

No Such Thing as a Free Safe Lunch: The Cost of Food Safety Regulation in the Meat Industry

Periodic discoveries of fresh or frozen meats contaminated with pathogens such as *E. coli* 0157:H7 and *Salmonella* have led the Food and Drug Administration (FDA) and the Food Safety Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) to mandate new quality-control regulations for the seafood, meat and poultry industries (FDA, 1994a,b; FSIS, 1996). These new regulations are designed to modernize the inspection system that has been recognized as ineffective in preventing microbial contamination (National Research Council, 1985, 1987).

Economic assessments of the proposed food safety regulations conducted by FDA and FSIS found that the potential benefits of these regulations could be on the order of billions of dollars, whereas the costs would be far less. These assessments imply that the benefits outweigh the costs by such a wide margin that the new regulations could be viewed as providing a virtual "free lunch" -- they imply that the meat industry could provide a substantial increase in the safety of its products, perhaps even completely eliminating all risk of foodborne pathogens, for less than 0.1 cent per pound of product.

The purpose of this paper is to develop an econometric model for the estimation of the plant-level costs of quality regulations such as the recent food safety regulations. The empirical model proposed in this study is based on the integration of Rosen's (1974) model of a competitive industry producing quality-differentiated products with Gertler and Waldman's (1992) model of a quality-adjusted cost function. Using plant-level data from the Census of

Manufactures, quality-adjusted cost functions are estimated for beef, pork and poultry slaughter and processing plants, and these cost functions are used to assess the potential costs of the new food safety regulations being imposed on the industry.

The FSIS analysis of the costs of the new regulations was based on an accounting methodology that assumed that the regulations have no effect on the overall operating efficiency of the production process and thus do not affect the variable cost of production. Under this assumption, the FSIS found that the cost of the regulations would be less than $100 million per year (in 1995 dollars), or less than 0.1 cent per pound of meat product. Assuming the regulations were 20 percent effective in reducing food pathogens, the estimated benefits range from $0.4 to $3.8 billion (Crutchfield *et al.*, 1997).

The econometric model developed in this study can be used to test the structure of the technology. Statistical tests strongly reject the assumption made in the FSIS study that variable cost of production is independent of product safety, showing that food safety regulations do affect the overall operating efficiency of meat slaughter and processing plants. This is an important result because, as shown by the data used in this study, over 95 percent of the cost of production in meat plants is variable cost associated with animal and labor inputs. Consequently, by assuming that regulations do not affect the operating efficiency of plants, the FSIS analysis assumed away the most significant component of the cost of the regulations. The econometric models estimated in this study indicate that the plant-level costs of the regulations, assuming they are 20 percent effective, are likely to be in the range of $750 million to $6.8 billion (1995 dollars). Whereas the FSIS estimates of regulatory costs average less than 0.1 cent per pound of meat product, the econometric models in this study imply costs in the range of 0.8 to 27 cents per pound, assuming the regulations are 20 percent effective. Alternatively, this study finds that for costs to be as low as those estimated by FSIS, the regulations would have to be completely ineffective. Thus, the findings of this study cast doubt on the proposition that there is a virtual free lunch in food safety regulation in the meat industry, and show that the costs of these regulations could well exceed the benefits estimated by FSIS.

The paper begins with background on food safety regulation and the methods used by government agencies to assess regulatory costs, and introduces the approach taken in this study. The next section presents theoretical and econometric models proposed for estimation of a quality-adjusted cost function for a competitive industry, followed by a presentation of econometric results. The final section discusses the use of quality-adjusted cost functions to estimate the costs of food safety regulation in the meat industry, and compares estimates based on these econometric models to the estimates produced by FSIS.

1. Background

The market for food safety is generally characterized by imperfect information about product quality, because important safety attributes such as the presence of microbial pathogens cannot be readily detected. Consumers, producers, and regulators all generally have imperfect information about the safety of food products. Nevertheless, consumers can learn about the quality and safety of food products through experience, and firms can establish reputations for product quality and safety. Recent experiences with ground beef contamination with the pathogen *E. coli* 0157:H7 demonstrate that producers face substantial legal liability and economic losses from producing and selling unsafe foods. Combined with the limited effectiveness of USDA inspections to detect food pathogens, it can be concluded that the safety of fresh meats and poultry is regulated largely through market mechanisms, with federal regulations playing a relatively minor role.

The presence of imperfect information in food markets is used frequently by economists as a justification for food safety regulation (e.g., Council for Agricultural Science and Technology, 1994), but whether or not a regulatory regime can be designed that yields benefits greater than costs is an empirical question that remains to be answered (Antle, 1995, 1996). Indeed, economists have long recognized (Demsetz, 1969) that the key question in regulatory design is not whether there are market failures, but rather whether regulations can be designed that generate benefits in excess of costs, a point that has been reiterated recently (Arrow *et al.*, 1996). Consistent with this view of regulation, the United States government began to subject new regulations to closer scrutiny in the 1980s. President Regan issued an Executive Order requiring federal agencies to conduct Regulatory Impact Assessments of major new regulations (Smith, 1984), and this order has remained largely intact under Presidents Bush and Clinton.

If effective, new food safety regulations could enhance the safety of the nation's food supply by reducing the presence of microbial pathogens in fresh and processed foods. Whether or not they are effective, the new regulations would be expected to raise the industry's cost of production, and these higher costs could have significant economic consequences for both producers and consumers. Ultimately, the costs of complying with food safety regulations in a competitive industry are largely passed on to consumers through higher prices.

The competitiveness of the meat slaughter and processing industry has long been a subject of debate in the livestock industry and among economists and government agencies. The most recent round of debate culminated in a review of concentration in the meat packing industry

(Packers and Stockyards Programs, 1996). Academic research provides some evidence of monopsony power being exerted by meat packing firms, but there is no evidence of monopoly power in product markets (Azzam and Anderson, 1996). The industry has become increasingly concentrated, with most of its output being produced in large plants owned by the four largest firms (Ollinger *et al.*, 1997). Some argue that food safety regulations place small firms and plants at an economic disadvantage, further hastening industry concentration (Crutchfield *et al.*, 1997). The beef industry has faced growing competition from pork and poultry, and some argue that differences in inspection requirements creates a cost disadvantage for the beef industry. Differential costs of complying with food safety regulations would in turn raise the cost of beef to consumers relative to other meats.

The regulatory impact assessments conducted by FDA and USDA utilized the scientific literature on food-borne illness to estimate the potential benefits of reducing such risks (see reviews in Council for Agricultural Science and Technology, 1994, and Caswell, 1995). Although one could always question some of the assumptions or methods used, there is nevertheless a scientific basis for these benefit estimates. However, on the cost side, there is little published research on the potential costs of food safety regulation in the food processing or meat packing industries. To estimate costs, both the FDA and 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 by multiplying them times the number of plants in each size category and summing over categories.

From an economic perspective, this accounting approach to cost estimation has several shortcomings. First, the cost estimates are based on limited data available to the agency, and in some cases these data must be supplemented with the subjective judgement of agency personnel. Just as regulators cannot effectively tailor process-based regulations to each plant, neither can they know the way that the implementation of regulations will impact a plant's operation and its cost of production. Considering the regulatory agency's vested interest in the regulations, subjective cost estimates may be biased downwards.

Second, in the application of the accounting approach, the costs of producing a safer product are assumed to be 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. This assumption of what Braeutigam and Pauly (1986) call *quality exogeneity* contradicts the fact that process-based quality control systems in food processing and meat packing are an integral part of the production process. In meat slaughter and processing, for example, one of the keys to the efficiency of modern, large scale plants is the speed of slaughter lines. Any regulation that slows line speeds will reduce the overall operating efficiency of the plant and raise average variable cost. This study shows that variable costs represent more than 95 percent of the total cost of production for large plants. Consequently, modifying production processes so as to achieve higher product quality can result in substantial increases in the cost of production. Data presented in this paper demonstrate that the increases in variable cost associated with higher quality can dwarf the fixed costs of quality control in meat slaughter and processing plants.

The purpose of this paper is to develop an econometric model for the estimation of the plant-level costs of quality regulations, such as recent food safety regulations, that can be made with data publicly available to researchers. This econometric approach overcomes limitations of the accounting approach utilized by regulatory agencies: first, it can be subjected to independent validation because it is based on publicly available data; second, it is based on data representing the industry's actual production technology; and third, the econometric approach provides the basis for specification tests, including a test for the dependence of variable cost of production on product safety, i.e., a test for quality exogeneity.

The empirical model proposed in this study is based on Rosen's (1974) model of a competitive industry producing quality-differentiated products, and on Gertler and Waldman's (1992) model of a quality-adjusted cost function. Using plant-level data available from the Census of Manufactures, quality-adjusted cost functions are estimated for beef, pork and poultry slaughter and processing plants, and these cost functions are used to assess the potential costs of the new food safety regulations being imposed on the industry. The importance of using plant-level data for this analysis is underscored by evidence that aggregate data for the industry fail to satisfy conditions for aggregation (Chambers, 1988) and by evidence that aggregation fails because of heterogeneity across plants (Bertin, Breshnahan and Roff, 1996). This finding seems particularly relevant in the meat industry where plants range in size from less than 10 employees to more than 1000.

Gertler and Waldman (1992) showed how a quality-adjusted cost function (i.e., a cost function for a production process in which output and product quality are treated as joint products) can be estimated econometrically. In their model, a nursing home is a firm with monopoly power in its local market, and quality is an endogenous variable unobserved by the econometrician. They showed that although quality is unobserved, variation in demand variables can be used to identify quality parameters in a quality-adjusted translog cost function. A key aspect of the Gertler-Waldman model is the spatial organization of the nursing home industry, which allows them to use spatial variation in the demand variables to identify the quality parameters in the cost function. The spatial organization of the nursing home industry does not characterize the meat industry, however, because there are many firms in the meat industry competing in what are best described as large regional, national, and even international markets. Consequently, the Gertler-Waldman technique of using variation in demand variables across firms to identify quality parameters in the quality-adjusted cost function cannot be used because many of the firms in the meat industry face similar demand conditions.

The safety of meat products (the presence or absence of microbial pathogens) is also not observable by the econometrician. Indeed, given that it is infeasible to test each product leaving a meat plant for the presence of pathogens, and that reliable tests do not exist for all major pathogens, meat producers themselves lack data on product safety. (Many plants conduct tests for pathogens but these data are closely held proprietary information). A major contribution of this study is to demonstrate that by combining a cost function with a hedonic model, economic data can be used to infer the costs of product safety.

2. Theory and Estimation of Quality-Adjusted Cost Functions Under Competition

In this section we describe a market in which competitive, price-taking firms produce a quality-differentiated product. Because the spatial organization of the market depends on the location of plants and not firms, we henceforth define a production unit as a plant, making the assumption that a sufficient number of firms (the owners of plants) are present in each market for competition to prevail. We shall consider several alternative assumptions about the spatial organization of the product and factor markets:

Assumption D1: All plants in the industry sell into the same market, e.g. a national market, and thus face the same demand conditions defined by the vector **Z** of demand variables (i.e., income, prices, and demographic variables).

Assumption D2: The product market is divided into regions. A plant located in the r^th^ region sells its product in the r^th^ regional market and faces demand conditions defined by the vector $\mathbf{Z}_r$ of demand variables.

Assumption S1: Each plant purchases an input vector **x** in the same market, e.g. a national market, and thus faces the same vector **W** of factor prices.

Assumption S2: Plants in the r^th^ region purchase inputs **x** in regional factor markets at prices $\mathbf{W}_r$.

Following Rosen's (1974) description of a competitive industry with product differentiation, we assume that there are demanders and suppliers of a quality-differentiated product sufficient to generate an equilibrium hedonic price equation for the industry. Let product demand be described by the function $Y^d = D(P, Q, \mathbf{Z})$, where P is the price of Y, product quality is described by a scalar index Q, and **Z** is a vector of other demand variables. The demand function satisfies the usual properties and $D_Q > 0$. Market supply is given by the function $Y^s = S(P, Q, \mathbf{W}, K)$, where **W** is a vector of factor prices and K is the industry capital stock. The supply function also satisfies conventional properties and $S_Q < 0$. Equating supply and demand yields an inverse hedonic price function $Q = F(P, \mathbf{Z}, \mathbf{W}, K)$ with the property that $F_P > 0$. Comparative static properties imply that derivatives with respect to **Z** are opposite in sign from the derivatives of the demand function, and the derivatives with respect to **W** and K have the same sign as the derivatives of the supply function with respect to these variables (these results are easily derived with constant elasticity supply and demand functions).

An individual firm faces both long-run and short-run decisions as in the conventional theory of the firm. In the short run, a firm chooses output to maximize expected net returns, taking capital and expected quality as given. Expected quality is taken as fixed in the short run because the production of quality is closely linked to a firm's capital stock and technology. Quality is produced in the meat sector and other food industries though the use of various quality control technologies, including the Hazard Analysis Critical Control Points (HACCP) technology required by new regulations (Crutchfield *et al.,* 1997). These quality control programs require investment in specific capital and management that are independent of the rate of output in any given time period, and thus are a part of a plant's fixed capital and management. Moreover, the ability of a plant to sell a product that is safer than average depends on its ability to establish a reputation for safe products. This safety reputation can be thought of as a form of the "brand name capital" discussed by Klein and Leffler (1981) and others (Stiglitz, 1989). Thus, in the short run, a plant chooses to produce a particular output y, given its planned quality q, its capital stock k, and variable factor prices **w**. Given its planned quality, a plant's expected product price is derived from the market equilibrium price function by solving $q = F(p, \mathbf{Z}, \mathbf{W}, K)$ for p. Letting a plant's cost function for output y and quality q be $C(y, q, \mathbf{w}, k)$, in the short run a plant chooses y to maximize expected net returns $\pi = py - C(y, q, \mathbf{w}, k)$ as in the neoclassical theory of the firm.

Implications for Econometric Estimation

If measurements of q were available, the cost function could be estimated using standard econometric methods with plant-level data. But q is not generally observed, so the inverse hedonic price function F(p, **Z**, **W**, K) can be substituted into the cost function to obtain C(y, F(p, **Z**, **W**, K), **w**, k) which is a function of observable variables. This procedure is mathematically similar to the procedure used by Gertler and Waldman, except that in their model q is replaced by the reduced-form quality supply function of the form G(y, **w**, **Z**, k). However, note that the hedonic function F defines the market equilibrium price–quality relationship which depends on the output price rather than the plant's output. Moreover, F depends on variables **Z**, **W** and K that shift the market supply function, whereas G depends on the firm's input price vector **w** and capital stock k.

Gertler and Waldman's analysis was concerned with a product market with the structure defined by Assumption D2, so that identification of the quality parameters in the cost function could be secured by variation in **Z** across observations. To implement a model based on Assumption D2, appropriate demand variables such as income and population are needed for each plant's market, and there would have to be enough variation in demand variables across markets to be useful statistically. In the case of meat plants, Assumption D1 is more plausible, especially for larger plants, because these plants export most of their product into regional, national and international markets. Clearly, in such cases plant-specific demand variables are not available to identify the quality parameters of the model. The difference between the model developed here and the Gertler-Waldman model is that the output price replaces output in the reduced-form model. Thus, even though the vector of demand variables **Z** does not vary across plants, the output price p does vary across plants and can be used to identify the quality parameters in the cost function. In the following section this model is used to specify and estimate cost functions for the meat industry.

3. Quality-Adjusted Translog Cost Functions for Meat and Poultry Plants

This section reports estimates of restricted, quality-adjusted translog variable cost functions C(y, q, w, k) for beef, pork and poultry plants in the United States. Variable cost is comprised of animal (M) and production labor (L) inputs (other variable costs such as energy are a very small share of cost and are assumed proportional to output and not included explicitly in the model). The full translog model is specified as

$$
\begin{aligned}
(1)\quad \ln C = {} & \alpha_0 + \alpha_M \ln w_M + \alpha_L \ln w_L + \tfrac{1}{2}\alpha_{MM} (\ln w_M)^2 + \tfrac{1}{2}\alpha_{LL} (\ln w_L)^2 + \alpha_{ML} \ln w_M \ln w_L \\
& + \beta_y \ln y + \tfrac{1}{2}\beta_{yy} (\ln y)^2 + \beta_{yq} \ln y \ln q + \beta_{yM} \ln y \ln w_M + \beta_{yL} \ln y \ln w_L \\
& + \beta_{yk} \ln y \ln k + \gamma_q \ln q + \tfrac{1}{2}\gamma_{qq} (\ln q)^2 + \gamma_{qM} \ln q \ln w_M + \gamma_{qL} \ln q \ln w_L \\
& + \gamma_{qk} \ln q \ln k + \delta_k \ln k + \tfrac{1}{2}\delta_{kk} (\ln k)^2 + \delta_{kM} \ln k \ln w_M + \delta_{kL} \ln k \ln w_L.
\end{aligned}
$$

Applying Shephard's lemma, the first-order condition for animal inputs is:

$$(2)\quad S_M = \alpha_M + \alpha_{MM} \ln w_M + \alpha_{ML} \ln w_L + \beta_{yM} \ln y + \gamma_{qM} \ln q + \delta_{kM} \ln k$$

where S_M is the animal cost share. The conditions for linear homogeneity of the cost function are

$$(3)\quad \alpha_M + \alpha_L = 1,\ \alpha_{Mj} + \alpha_{Lj} = 0,\ j=M,L,\ \beta_{yM} + \beta_{yL} = 0,\ \gamma_{qM} + \gamma_{qL} = 0,\ \delta_{kM} + \delta_{kL} = 0.$$

Note that symmetry of α_{ML} and α_{LM} and the condition $\alpha_{Mj} + \alpha_{Lj} = 0$, j=M,L, imply that $\alpha_{MM} = \alpha_{LL} = -\alpha_{LM} = -\alpha_{ML}$.

Wholesale markets for meat products differentiate three quality dimensions, one related to taste (represented by USDA grades for red meats), one related to safety, and a third that represents other non-food quality aspects of the product such as the quality of packaging, reliability of delivery, etc., for which a buyer may be willing to pay a price premium (referred to henceforth as reliability). Quality grades assigned to red meats by USDA inspectors are based on observable characteristics related to the taste and tenderness of the meat. All meat products are also inspected for safety by either state or federal agencies, but important safety characteristics such as microbial pathogen contamination are not observable using the conventional (visual, smell, touch) inspection procedures. Therefore, during 1987 and 1992 (the years used in this study) the market for products meeting higher safety standards had to be supported by firms' reputations for quality and safety. This remains true up to the present time, despite the introduction of new USDA regulations, because of the high cost of testing every fresh meat product for pathogens and the lack of reliable tests for all pathogens.

For estimation purposes, quality is modeled as q = q(G,S,R) where G represents taste and other attributes related to government grades, S represents safety, and R represents other quality attributes (reliability). Equating this quality function to the inverse hedonic function q = F(p, **Z**, **W**, K), utilizing a log-linear representation, and solving for S, we have:

$$(4) \qquad \ln S = \tau_0 + \tau_G \ln G + \tau_R \ln R + \tau_p \ln p + \tau_z \ln Z + \tau_M \ln W_M + \tau_L \ln W_L + \tau_K \ln K.$$

It is a straightforward exercise to show that this is the exact form of the hedonic function if the aggregator function q(G,S.R) and the market demand and supply equations are log-linear. Observe that by solving this function in terms of safety S, units of safety are being used as the numeraire units of quality. Thus, in this model units of quality are equivalent to units of safety.

USDA grades are not observed in the data, but because most plants buy livestock from markets in lots that are not substantially differentiated by quality (Jones *et al.*, 1992), the average grade of meat produced by plants should be randomly distributed across plants. Thus, meat grade is modeled simply as $\ln G = \mu_G + \epsilon$, where μ_G is a constant ϵ is an independently distributed random variable with mean zero and constant variance. Equation (4) must satisfy zero homogeneity in product price, input prices and income because it is derived from supply and demand functions (this is demonstrated by deriving equation (4) explicitly from log-linear demand and supply equations). The units of quality are arbitrary, allowing one of the parameters to be normalized to unity, so let $\tau_p = 1$ without loss of generality. Interpreting Z as income, the zero homogeneity condition is $\tau_M + \tau_L + \tau_Z = -1$. Thus, even when there is no variation in income across plants (as under Assumption D1), the income elasticity τ_Z can be identified using the zero homogeneity property of the hedonic model.

In models with unobserved variables, the intercept term $(\tau_0 + \mu_G)$ is not identified. The industry capital stock K does not vary across plants so its parameter τ_K cannot be identified. In estimation these unidentified parameters are absorbed into the parameters of the reduced form, so to simplify the presentation of the model the parameters τ_0, μ_G and τ_K are henceforth excluded.

There is spatial variation in livestock prices due to differences in feed prices and transportation costs, and there also are regional wage rate differences. Therefore, Assumption S2 is maintained and factor prices paid by the plant are used in the hedonic function. Maintaining Assumption D1, that income and other demand variables do not vary across plants, parameter τ_Z is dropped from the model. With these modifications, equation (4) can be rewritten as:

$$\text{(5)} \qquad \ln S = \tau_R \ln R + \ln p + \tau_M \ln w_M + \tau_L \ln w_L + \epsilon.$$

With the linear homogeneity conditions (3) imposed, substituting (5) into (1) and (2) gives the reduced-form cost function and share equation:

$$\text{(6)} \qquad \ln C = \alpha_0 + (\alpha_M + \gamma_q \tau_M) \ln w_M + (1 - \alpha_M + \gamma_q \tau_L) \ln w_L$$

$$+ (\tfrac{1}{2}\alpha_{MM} + \tfrac{1}{2}\gamma_{qq}\tau_M^2 + \gamma_{qM}\tau_M) (\ln w_M)^2 + (\tfrac{1}{2}\alpha_{MM} + \tfrac{1}{2}\gamma_{qq}\tau_L^2 - \gamma_{qM}\tau_L) (\ln w_L)^2$$

$$+ (- \alpha_{MM} + \gamma_{qM}\tau_L - \gamma_{qM}\tau_M + \gamma_{qq}\tau_M \tau_L) \ln w_M \ln w_L + \beta_y \ln y + \tfrac{1}{2}\beta_{yy} (\ln y)^2 + \beta_{yq} \ln R \ln p$$

$$+ \beta_{yq} \ln y \ln p + (\beta_{yM} + \beta_{yq} \tau_M) \ln y \ln w_M + (-\beta_{yM} + \beta_{yq} \tau_L) \ln y \ln w_L + \beta_{yk} \ln y \ln k +$$

$$+ \gamma_q \tau_R \ln R + \gamma_q \ln p + (\gamma_{qM}\tau_R + \gamma_{qq}\tau_R \tau_M) \ln R \ln w_M + (\gamma_{qM} + \gamma_{qq}\tau_M) \ln p \ln w_M$$

$$+ (-\gamma_{qM}\tau_R - \gamma_{qq}\tau_R \tau_L) \ln R \ln w_L + (-\gamma_{qM} - \gamma_{qq}\tau_L) \ln p \ln w_L + \gamma_{qk}\tau_R \ln k \ln R$$

$$+ \gamma_{qk}\tau_R \ln k \ln p + (\gamma_{qk}\tau_M + \delta_{kM}) \ln k \ln w_M + (\gamma_{qk}\tau_L - \delta_{kM}) \ln k \ln w_L + \tfrac{1}{2}\gamma_{qq}\tau_R^2 (\ln R)^2$$

$$+ \tfrac{1}{2}\gamma_{qq} (\ln p)^2 + \gamma_{qq}\tau_R \ln R \ln p + \delta_k \ln k + \tfrac{1}{2}\delta_{kk} (\ln k)^2 + u.$$

$$(7) \qquad S_M = \alpha_M + (\alpha_{MM} + \gamma_{qM} \tau_M) \ln w_M + (\alpha_{ML} + \gamma_{qM} \tau_L) \ln w_L + \beta_{yM} \ln y + \gamma_{qM} \tau_R \ln R$$

$$+ \gamma_{qM} \ln p + \delta_{kM} \ln k + \gamma_{qM} \epsilon.$$

In equation (6), u is a heteroscedastic error term that contains model parameters and variables from the interactions of the error term ϵ with variables in the cost function. This error term is derived explicitly in Appendix A.

As discussed by Gertler and Waldman, the parameters of this model are identified by virtue of the normalization in the quality equation, the linear homogeneity restrictions of the cost function, and the across-equation restrictions. In addition, this model is identified by the zero homogeneity restriction in the hedonic function. To illustrate, set the quadratic terms involving γ_{qq} and γ_{qj} , j = M,y,k equal to zero. Then one can readily verify by inspection that the linear output price term (ln p) identifies γ_q , the intercept of the share equation identifies α_M , and the reduced form coefficients on ln w_M and ln w_L can be used to solve for τ_M and τ_L.

Data, Estimation and Testing

The data were stratified into samples for beef, pork, and poulty; and into groups of large plants (producing more than 100 million pounds annually) and small (producing less than 100 million pounds). This stratification was chosen for the analysis based on several criteria. First, as Table 1 shows, most of the industry's output is produced by larger plants, suggesting that the large group includes all of the large scale commercial plants, whereas the small group contains plants that operate at a much smaller scale. These small plants tend to produce specialty products and compete in local or regional markets, and thus, are likely to have different technologies than the large scale plants. Second, this stratification contains enough plants operated by different firms to satisfy the Census' disclosure rules, so that the summary statistics and parameter estimates can be published. Third, this stratification provides a sample size large enough for each group to provide adequate degrees of freedom and variation in the data for statistical estimation. Table 1 also shows 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).

Equations (6) and (7) were estimated using plant-level data from the Census of Manufactures for SIC code 2011 (beef and pork slaughter and processing) and SIC code 2015 (poultry slaughter and processing) for the years 1987 and 1992. As described in Appendix B, product categories at the seven-digit level were used to identify beef, pork and poultry plants and to measure output and input quantities and prices. Although some observations were discarded because of missing data and outliers, these remaining data represent virtually all of the output reported by the Census for the industry in each year. The equation system was estimated using the nonlinear seemingly unrelated regression routine in the SAS Model Procedure.

The error term in the cost function equation (6) is heteroscedastic due to the error term introduced when equation (5) is substituted for q in equation (6). The effect of heteroscedasticity was investigated by comparing unweighted models to models weighted by exogenous variables. Parameter estimates and implied costs of safety regulation (discussed in the following section) were similar with the two approaches, so the unweighted results are reported. It was not possible to employ an estimator that explicitly accounted for the exact form of the heteroscedasticity (as discussed in Appendix A) because the software needed for implementation of this type of estimation procedure was not available at the Census site where the data must be used.

The following specification tests were performed: to test hypotheses for the pooling of data across years and across plant size groups;. for the exogeneity of safety with respect to variable cost (the significance of the safety variable in the cost function); and for the functional form with respect to safety (log-linear versus log-quadratic) (Table 3). The pooling, safety exogeneity, and functional form tests were constructed as nested Chi-square tests following the procedures described in Gallant and Jorgenson (1979). The tests for pooling data from 1987 and 1992 show that pooling cannot be rejected for beef and poultry but is rejected for pork at the 1 percent level. The tests for pooling small and large plant sizes shows that the hypothesis is rejected for beef, pork and poultry. Because the sample sizes do not allow the samples to be stratified by both years and plant sizes, the remainder of the tests maintain pooling of 1987 and 1992 data, and stratify by plant size.

Under the maintained hypothesis that the cost function is translog, safety exogeneity holds if and only if the parameters γ_q, γ_{qq}, and γ_{qi}, i=M,L,K in equation (1) are equal to zero. Table 3 shows that this hypothesis is strongly rejected. The test for log-linearity of the cost function in safety is a test for the joint significance of the parameters γ_{qq} and γ_{qi}, i=M,L,K. This hypothesis is clearly rejected for large plants for all three meat types, but is not strongly rejected for small plants. Gertler and Waldman (1992) assumed that the parameter $\gamma_{qq} = 0$ in their analysis of the nursing home industry. Examining the t-statistics for these parameters in Tables 4, 5 and 6 shows that these parameters are statistically significant for large beef and poultry plants, indicating that in some cases the assumption that this parameter is zero may not be consistent with the data.

Tables 4, 5 and 6 present parameter estimates of cost and hedonic functions for beef, pork and poultry, for small and large plant groups. Full translog cost models and models log-linear in safety are presented. All of the statistically significant factor price parameters in the hedonic functions have the theoretically implied negative sign. The parameter of the management variable, the proxy for the reliability dimension of quality, has the expected negative sign in some cases and positive signs in some cases, suggesting that this variable may not be an appropriate proxy for residual quality attributes such as reliability. In results not reported here, regional per capita income was not statistically significant or had the theoretically incorrect sign, and similar results were obtained with other demographic variables such as education. These findings support the hypothesis that meat markets are national and hence regional variation in demand variables is not adequate to identify the parameters of the hedonic function. Hence, hypothesis D1 appears to be consistent with the data.

To interpret the implications of the models, Table 7 presents the elasticities of cost with respect to output and safety. The output elasticities were computed at each data point and averaged. Table 7 shows that both small and large beef and pork plants are operating at close to constant returns to variable inputs (recall that these restricted cost functions hold capital fixed, so these cost elasticities cannot be interpreted as measures of returns to scale). Poultry plants, in contrast, appear to exhibit increasing returns to variable inputs.

In the safety dimension, the full quadratic translog models indicate a positive elasticity of cost with respect to safety, as predicted by economic theory. The elasticities indicate increasing returns to safety for all but small beef plants. Only the beef elasticities indicate a substantial difference between small and large plants. Table 7 also presents the safety cost elasticities from the log-linear models reported in Tables 4, 5 and 6. These elasticities are all highly statistically significant. Recall that the hypothesis of log-linearity in safety was not rejected for small plants but was rejected for large plants, so the large plant estimates may be biased by the imposition of the restriction. The estimates for small plants imply somewhat lower elasticities, but the pattern between small and large plants is the same as with the mean elasticities implied by the full quadratic model.

4. Benefits and Costs of Food Safety Regulations

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 USDA's mandatory HACCP regulations and standard operating procedures are process design standards and it is unclear how effective they will be in reducing pathogen contamination. Lacking experience with the performance standards that are being implemented for *Salmonella* and generic *E. coli*, it is also unclear how effective they will be. In the FSIS's initial Regulatory Impact Assessment, it was assumed that the regulations would be 90 percent effective in eliminating risks from pathogen contamination. After being criticized for this assumption, FSIS concluded "...there is insufficient knowledge to predict with certainty the effectiveness of the rule, where effectiveness refers to the percentage of pathogens eliminated at the manufacturing stage" (FSIS, 1995, as quoted in Crutchfield *et al.* 1997). In the regulatory impact assessment of the final rule, FSIS utilized a range of effectiveness from 10 to 100 percent. The only other 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 were 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 are imposed also must be estimated. Recall that the units of quality in the econometric model are defined in 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 percent, 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. For example, if the new regulations are 20 percent effective and the level of safety prior to their implementation was $S = 70$ percent, then the regulations would increase the level of safety by $0.2(100 - 70) = 6$ percentage points, or by $6/70 = .0857$ 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.

The econometric cost functions presented above embody the technology utilized by the industry during the 1987-1992 period. To use these cost functions to estimate the additional variable costs that would be associated with new regulations, we assume that prior to the imposition of the regulations plants are producing products that are S_0 percent safe, and after the new regulations are imposed plants would produce products that are $S_R > S_0$ percent safe. This higher level of safety is obtained by implementing changes in plant operation that improve safety. It should be noted that the meat industry utilized HACCP and related quality-control methods prior to the new regulations, and that the new regulations amount to imposing a uniform set of quality control standards on the industry. It is argued by economists that mandatory process standards are likely to be more costly than the technologies that would be voluntarily adopted by firms to meet an equivalent performance standard (Council of Economic Advisers, 1990). According to this logic, the costs implied by a cost function estimated from observed plant data prior to the implementation of regulations might underestimate the costs of meeting mandatory process standards.

The annual net benefits from implementing a regulation that is e percent effective, starting from a safety level of S percent, in $i = 1,...,N$ plants is

$$NB(e,S) = TB \cdot e - (N_{small} \cdot VC_{small} \cdot E_{small} + N_{large} \cdot VC_{large} \cdot E_{large}) \cdot e(100-S)/S$$
$$- N_{small} \cdot FC_{small} - N_{large} \cdot FC_{large}$$

where

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

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

TB = total annual benefits of eliminating food borne disease in meat and poultry

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

FC_i = annual fixed cost of implementing the regulations for i = small, large plants.

Note that this cost calculation is based on an average elasticity and an average variable cost for the small and large plant groups. Alternatively, it is possible to calculate the cost for each plant in the data. The approach using mean values to represent small and large plant groups is used here because it allows the regulatory costs to be estimated with the data contained in Tables 1, 2 and 7. The cost calculations for each plant in the data have to be made with the confidential Census data that are not readily accessible by other researchers.

According to FSIS, if the new regulations are 20 percent effective, the benefits would be in the range of $400 million to $3.8 billion (in 1995 dollars). The annual costs of the regulations were estimated to be less than $100 million (Crutchfield *et al.*, 1997). Using the full quadratic cost function parameter estimates presented in Tables 4, 5 and 6, the costs of this 20% improvement in safety were estimated for prior safety levels of S = 50, 70 and 90 percent. Table 8 shows that the increase in total variable cost for beef, pork and poultry plants is estimated to range from $752 million (1995 dollars) assuming products were 90 percent safe prior to the new regulations, to $6.8 billion assuming products were 50 percent safe prior to the new regulations. Combined with the FSIS estimate of annual fixed costs of about $60 million, the data in Table 8 show that the costs of the new regulations are likely to exceed the benefits by a substantial margin if the prior safety level is in the 50 to 70 percent range, or if the benefits are in the lower range of estimated values. If the prior safety level is in the 70 to 90 percent range and the benefits are in the higher range of estimated values, the benefits may exceed the costs. Thus, the data presented in Table 8 cast doubt on the FSIS conclusion that the benefits of the regulations are likely to exceed the costs by a wide margin over the full range of their benefit estimates.

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 8 shows that the regulatory cost per pound could be as high as 27 cents for small beef plants operating at a safety level of 50 percent before the regulations. The per pound cost falls to as low as 0.8 cents per pound for large poultry plants operating at a prior safety level of 90 percent.

The data in Table 8 also show that the costs are generally higher for small beef and poultry plants than large plants, with small plants experiencing a 20 to 40 percent greater cost increase than the large plants. However, this difference does not appear to hold for pork plants. The data in Table 8 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. However, recall from

Table 2 that small pork and poultry plants appear to receive a higher price for their products in both gross and net terms, perhaps because they are producing specialty products that are differentiated from the products of larger plants. This fact suggests that small pork and poultry plants may be able to absorb the costs of regulations and remain profitable. The situation appears less favorable for small beef plants because they appear to compete directly with large beef plants and have lower profit margins.

The regulatory cost difference between small and large plants also would depend on whether small plants produced safer products than large plants or *vice versa*. If small plants produce safer products than large plants, then small plants would need to increase their safety by a smaller amount than large plants to achieve a given level of safety, and thus would be affected relatively less than large plants by uniform safety regulations. 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 8 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, pork and poultry, and thus further encourage the observed trend in consumption away from beef towards pork and poultry (see 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.

The estimated cost functions can also be used to infer the effectiveness of the regulations from an independent estimate of regulatory costs. According to the FSIS cost estimates, the variable costs of complying with the regulations is expected to be far less than $100 million per year. Utilizing the range of the safety elasticities with respect to cost in Table 7 and the data presented in Tables 1 and 2, one can readily infer that the implied effectiveness of the regulations is approximately zero. Thus, according to the cost function estimates in Tables 4, 5 and 6, only an ineffective regulation could have the impact on the cost of production estimated by FSIS. This result is obtained because the FSIS cost estimates do not include the impact of regulations on operating efficiency estimated in this study.

5. Conclusions

This study combined Rosen's (1974) model of a competitive industry producing quality-differentiated products with Gertler and Waldman's (1992) model of a quality-adjusted cost function to estimate quality-adjusted cost functions for the meat and poultry industry using data from the Census of Manufactures. These cost functions were used to estimate the costs of new regulations being imposed on the meat industry. The FSIS estimated that the costs of new regulations would be far less than the benefits, and so low as to imply a virtual free lunch in food safety regulation. In contrast, the cost estimates obtained from the econometric model developed in this study imply that the costs of the new regulations are likely to be an order of magnitude or more larger than the cost estimates of FSIS, and could well exceed the benefits estimated by FSIS. This study thus leads to the conclusion -- presumably not surprising to many economists -- that there is no such thing as a free lunch in food safety regulation. In addition, the results of this study suggest that there could be significantly different economic impacts on small and large beef plants in the industry, and that the costs of food safety regulation could be substantially higher for beef plants than for pork or poulty.

The impacts estimated in this study are the aggregation of the plant-level costs and do not account for the market equilibrium effects of cost increases on producers or consumers. Clearly, if the regulatory costs resulted in higher market prices, then a complete analysis of the economic effects of the regulations would need to examine these market equilibrium effects.

The method developed in this study could be applied to other competitive industries that produce quality-differentiated products. Food safety is also a concern in the seafood and shellfish industry and with new regulations being implemented similar to those being implemented in the meat industry. Utilizing a methodology similar to USDA's, the FDA's regulatory impact assessment concluded that the new food safety regulations would yield benefits that exceed the costs by a wide margin. The findings of this study suggest that the costs of the regulations may be higher than those estimated by FDA using an accounting methodology.

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Appendix A. Cost Function Error Structure

Substituting S from equation (5) for q in equation (1), it follows that the error term *u* in equation (6) can be written as:

$$u = A\epsilon + \tfrac{1}{2}\gamma_{qq}\,(\epsilon^2 + 2B\epsilon),$$

where

$$A = \beta_{yq}\ \ln y + \gamma_q + \gamma_{qM}\ \ln w_M - \gamma_{qM} \ln w_L + \gamma_{qk} \ln k$$

$$B = \tau_R \ln R + \ln p + \tau_M \ln w_M + \tau_L \ln w_L$$

Thus *u* is a linear function of the exogenous variables in the model, so it follows that the variance of *u* is a quadratic function of these variables.

Appendix B. Census of Manufactures Data

The data utilized in this study were derived from the Longitudinal Research Data maintained by the Center for Economic Studies, Bureau of the Census. Data were obtained from extracts of the labor, materials, and product files for 1987 and 1992 for SIC codes 2011 (Meat Packing Plants) and 2015 (Poultry Slaughter and Processing Plants). Beef plants were selected which produced products in the 7-digit categories 2011112 (carcass beef) and 2011114 through 2011131 (boxed and ground beef). Pork plants were selected that produced products in the categories 2011412 (slaughtered pork) and 2011417 through 2011661 (processed pork). Poultry plants were selected that produced products in the categories 2015100 through 2015400 (chicken and turkey slaughter and processing). Output prices were defined implicitly as total value of product divided by total weight.

Input quantity and price variables were defined as follows:

Animal inputs: Total weight of cattle for beef, hogs for pork, and chickens and turkeys for poultry. Prices computed as total cost divided by total weight.

Production Labor: Production worker hours. Wage rate calculated as total production worker wages divided by production worker hours.

Capital: value of plant and equipment at the beginning of the production period.

Management: total wages salaries paid to employees not classified as production workers.

Per capita income and other demographic variables for economic regions were constructed using income, population and other data from the Census of Population for 1990 at the county level. These variables were aggregated to the economic areas defined by the Bureau of Economic Analysis (Johnson, 1995).

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.

Table 2. Means (Standard Deviations) of Variables from Census of Manufactures Data, 1992 (1995 dollars)

	Beef		Pork		Poultry	
	Small	Large	Small	Large	Small	Large
Total Product Shipped (1000 lbs)	38,933 (30,196)	387,616 (237,781)	19,014 (23,032)	334,791 (154,319)	47,480 (29,080)	170,870 (66,281)
Animal Input (1000 lbs)	75,090 (65,655)	672,491 (440,783)	28,073 (34,512)	528,092 (231,505)	82,271 (70,009)	219,350 (86,773)
Production Worker Hours (1000 hrs)	209 (185)	2,046 (1895)	167 (173)	1,856 (886)	711 (594)	1,581 (797)
Capital ($1000)	2,560 (2,436)	27,883 (24,161)	4,588 (11,142)	34,983 (28,702)	10,239 (11,863)	18,528 (12,247)
Meat Price ($/lb)	0.58 (0.164)	0.69 (0.148)	0.46 (0.157)	0.42 (0.080)	0.33 (0.125)	0.29 (0.078)
Wage Rate ($/hr)	8.22 (2.023)	7.93 (1.074)	7.96 (2.179)	8.61 (1.359)	6.63 (1.369)	6.72 (1.145)
Product Price ($/lb)	1.12 (0.204)	1.15 (0.209)	1.11 (0.317)	0.79 (0.139)	0.72 (0.288)	0.60 (0.159)
Animal Input Cost Share	0.97 (0.025)	0.99 (0.006)	0.92 (0.060)	0.97 (0.015)	0.89 (0.103)	0.92 (0.028)
Average Animal and Labor Cost ($/lb)	1.08 (0.251)	1.13 (0.214)	0.72 (0.188)	0.63 (0.070)	0.60 (0.378)	0.404 (0.118)
Per Capita Income in Market Area ($)	13,390 (2,712)	13,249 (1,562)	13,794 (2,362)	13,805 (1,411)	13,560 (2,645)	13,130 (2,220)
Management ($1000)	568 (501)	2,955 (2,332)	624 (903)	3,788 (3,177)	1,295 (1,351)	2,186 (1,960)

Table 3. Hypothesis Test Statistics (Chi-square variates with degrees of freedom and significance levels in parentheses)

Test	Beef	Pork	Poultry
Pooling Years	21.92 (19, 0.288)	36.21 (19, 0.010)	24.76 (19, 0.169)
Pooling Size	37.44 (19, 0.007)	39.79 (19, 0.003)	40.86 (19, 0.003)
Safety Exogeneity			
–Small Plants	859.85 (5, 0)	183.28 (5, 0)	114.79 (5, 0)
–Large Plants	146.83 (5, 0)	39.58 (5, 0)	42.41 (5, 0)
Log-Linearity in Safey			
–Small Plants	5.13 (4, 0.274)	7.82 (4, 0.098)	9.69 (4, 0.046)
–Large Plants	45.83 (4, 0)	32.65 (4, 0)	27.53 (4, 0)

Table 4. Iterated Nonlinear SUR Estimates of Beef Plant Cost Functions (t-statistics in parentheses)

Cost Function	Small Plants		Large Plants	
Cost Function:				
Intercept	0.032	-0.618	-5.598	-7.606
	(0.03)	(-0.50)	(-1.13)	(-1.73)
Animal Price	0.862	0.861	1.006	1.008
	(39.84)	(42.26)	(57.04)	(68.82)
(Animal Price)^2	0.008	0.007	-0.005	0.005
	(1.49)	(1.68)	(-1.70)	(2.08)
(Animal Price) * (Output)	0.019	0.019	0.002	0.003
	(9.80)	(9.47)	(1.87)	(2.06)
(Animal Price) * (Quality)	0.002		-0.018	
	(0.30)		(-6.64)	
(Animal Price) * (Capital)	-0.008	-0.008	-0.002	-0.004
	(-5.35)	(-5.16)	(-2.68)	(-6.15)
Output	1.039	1.212	1.653	2.505
	(5.00)	(5.86)	(1.97)	(3.12)
(Output)^2	0.013	-0.003	-0.020	-0.076
	(0.97)	(-0.27)	(-0.49)	(-1.93)
(Output) * (Quality)	0.073		-0.048	
	(1.95)		(-0.65)	
(Output) * (Capital)	-0.026	-0.008	-0.008	0.040
	(-1.39)	(-0.48)	(-0.26)	(1.34)
Quality	0.260	0.941	2.068	0.848
	(0.88)	(17.84)	(1.60)	(14.09)
(Quality)^2	0.002		-0.380	
	(0.05)		(-2.68)	
(Quality) * (Capital)	-0.003		0.088	
	(-0.12)		(1.79)	
Capital	0.009	-0.074	-0.199	-0.468
	(0.07)	(-0.63)	(-0.71)	(-1.79)
(Capital)^2	0.016	0.009	0.008	-0.0004
	(2.54)	(1.51)	(0.68)	(-0.04)
1992 Dummy	0.020	0.031	-0.023	-0.024
	(0.65)	(1.03)	(-1.29)	(-1.35)
Hedonic Function:				
Animal Price	-0.863	-1.172	-0.749	-0.758
	(-7.52)	(-7.03)	(-9.83)	(-9.46)
Wage Rate	-0.058	.036	-0..401	-0.344
	(-0.79)	(0.35)	(-4.68)	(-4.09)
Management	-0.009	-0.009	-0.005	-0.005
	(-0.89)	(-0.91)	(-0.72)	(-0.54)

Table 5. Iterated Nonlinear SUR Estimates of Pork Plant Cost Functions (t-statistics in parentheses)

Cost Function	Small Plants		Large Plants	
Cost Function:				
Intercept	5.024 (2.50)	4.700 (3.01)	0.620 (0.09)	-2.707 (-0.48)
Animal Price	0.803 (22.03)	0.782 (26.34)	1.038 (23.09)	1.035 (25.32)
(Animal Price)^2	0.036 (3.08)	0.030 (4.04)	0.024 (3.24)	0.027 (4.17)
(Animal Price) * (Output)	0.034 (10.27)	0.035 (10.50)	0.007 (2.23)	0.010 (2.71)
(Animal Price) * (Quality)	0.005 (0.45)		-0.024 (-2.91)	
(Animal Price) * (Capital)	-0.012 (-4.44)	-0.012 (-4.71)	-0.008 (-3.62)	-0.011 (-4.55)
Output	-0.248 (-0.93)	-0.067 (-0.26)	1.394 (1.07)	2.389 (2.41)
(Output)^2	0.083 (4.71)	0.073 (4.16)	-0.046 (-0.88)	-0.126 (-2.75)
(Output) * (Quality)	-0.032 (-0.66)		0.572 (2.65)	
(Output) * (Capital)	-0.025 (-1.50)	-0.026 (-1.52)	0.061 (1.08)	0.184 (4.20)
Quality	0.762 (1.93)	0.450 (6.02)	-2.247 (-1.02)	0.662 (9.47)
(Quality)^2	-0.040 (-0.79)		0.109 (0.56)	
(Quality) * (Capital)	0.009 (0.20)		-0.445 (-4.08)	
Capital	0.195 (1.32)	0.186 (1.35)	-0.493 (-0.67)	-1.106 (-2.95)
(Capital)^2	-0.005 (-0.78)	-0.002 (-0.35)	-0.009 (-0.40)	-0.063 (-3.64)
1992 Dummy	0.004 (0.10)	-0.002 (-0.04)	0.061 (2.32)	0.035 (1.32)
Hedonic Function:				
Animal Price	-0.916 (-5.19)	-0.859 (-5.67)	-1.425 (-4.94)	-0.956 (-4.55)
Wage Rate	.068 (0.45)	.054 (0.040)	-0.116 (-0.52)	-0.121 (-0.73)
Management	0.068 (1.73)	-0.004 (-0.15)	0.005 (0.22)	-0.031 (-1.97)

Table 6. Iterated Nonlinear SUR Estimates of Poultry Plant Cost Functions (t-statistics in parentheses)

Cost Function	Small Plants		Large Plants	
Cost Function:				
Intercept	1.761 (0.81)	1.010 (0.50)	-42.949 (-2.53)	-8.725 (-0.57)
Animal Price	0.686 (8.17)	0.703 (8.26)	1.165 (14.62)	1.171 (13.50)
(Animal Price)^2	0.068 (5.33)	0.049 (3.35)	0.074 (11.39)	0.068 (10.07)
(Animal Price) * (Output)	0.052 (6.22)	0.046 (5.48)	0.004 (0.55)	0.006 (0.69)
(Animal Price) * (Quality)	0.049 (2.94)		-0.018 (-2.10)	
(Animal Price) * (Capital)	-0.020 (-3.03)	-0.017 (-2.59)	-0.009 (-2.24)	-0.011 (-2.83)
Output	-0.142 (-0.31)	-0.044 (-0.10)	8.821 (3.13)	4.319 (1.58)
(Output)^2	0.153 (4.75)	0.152 (4.62)	-0.336 (-2.70)	-0.212 (-1.67)
(Output) * (Quality)	0.137 (1.93)		0.736 (3.87)	
(Output) * (Capital)	-0.270 (-6.63)	-0.271 (-6.52)	0.083 (0.94)	0.164 (2.00)
Quality	0.057 (0.08)	0.464 (7.54)	-5.427 (-2.38)	0.349 (6.59)
(Quality)^2	0.027 (0.38)		0.467 (4.91)	
(Quality) * (Capital)	-0.089 (-1.34)		-0.212 (-2.85)	
Capital	0.931 (2.91)	0.875 (2.75)	-1.076 (-1.12)	-2.157 (-2.37)
(Capital)^2	0.128 (7.55)	0.129 (7.26)	-0.005 (-0.18)	0.012 (0.43)
1992 Dummy	-0.089 (-2.08)	-0.093 (-2.12)	0.004 (0.17)	0.030 (1.11)
Hedonic Function:				
Animal Price	-0.917 (-8.75)	-0.960 (-6.50)	-1.145 (-7.75)	-0.831 (-6.96)
Wage Rate	-0.770 (-7.23)	0.016 (0.08)	-0.384 (-1.92)	-0.371 (-2.26)
Management	-0.002 (-0.05)	0.017 (0.35)	0.037 (1.68)	0.123 (2.40)

Table 7. Cost Elasticities for Output and Safety

	Beef		Pork		Poultry	
	Small	Large	Small	Large	Small	Large
Output Elasticity	1.04	0.96	0.99	1.04	0.71	0.86
Safety Elasticity						
– Quadratic	1.14	0.77	0.47	0.63	0.62	0.52
– Linear	0.94	0.85	0.45	0.66	0.46	0.35

Note: Elasticities based on parameters in Tables 4, 5 and 6.

Table 8. Estimated Increase in Variable Costs of Production for a 20% Improvement in Safety (Industry Cost in Million $1995)

	Beef		Pork		Poultry		
	Small	Large	Small	Large	Small	Large	Total
Base Safety = 50%							
Industry Cost	553.1	3,460.5	63.4	977.8	343.9	1,372.2	6,770.9
Cost per Lb. of Product	0.273	0.194	0.076	0.089	0.083	0.070	NA
Base Safety = 70%							
Industry Cost	237.0	1,483.1	27.2	419.1	147.4	588.1	2,901.8
Cost per Lb. of Product	0.117	0.083	0.032	0.038	0.036	0.030	NA
Base Safety = 90%							
Industry Cost	61.5	384.5	7.0	108.6	38.2	152.5	752.3
Cost per Lb. of Product	0.030	0.022	0.008	0.010	0.009	0.008	NA

Note: Base safety is the level of product safety prior to the 20% improvement in safety.

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