A Model of the Implementation of Quality Management Systems for Credence Attributes

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Abstract: We develop a model of the impact of food quality management systems (QMS) on competitiveness and markets. QMS seek to control the quality of a product as determined by the array of individual attributes it possesses. To date only a few studies have attempted to better understand the effect of the introduction of quality management systems. No model has been introduced which captures the interactions within the supply chain and at the interface with consumers when these systems are introduced.

Keywords: Product Quality, Quality Assurance, Supply Chain

1. Introduction

It is clear that quality and quality assurance have become more central features of international and domestic markets for food products. It is also clear that the impact of the implementation of quality management systems on firms' viability and profitability have not been analyzed sufficiently. Over the last decade many quality management systems were implemented voluntarily, quasi-voluntarily, or as mandated by government regulation. However, most economic models focus only on the relationship between consumers and firms and how the consumers' ability to perceive quality influences how markets for quality work. For example, Segerson (1999) examines the question of whether a voluntary approach to food safety is likely to lead to adequate consumer protection, also allowing for the possibility of government intervention. In reality, the implementation of quality management systems affects relations within the supply chain and at the interface with the consumer. There are only a few models that emphasize both communication along the supply chain and with the final consumer. Caswell, Bredahl, and Hooker (1998), for example, propose a model which incorporates transaction and regulatory compliance costs to analyze the influence of the implementation of a quality management system, or, as they call it, Metasystem, on the company.

In this paper, we propose an analysis of a firm's behavior within a supply chain. We describe the behavior of firms regarding quality management when the essential quality attribute of the product is not directly observable, i.e., is a credence attribute. We present a review of the development of the field of quality management over the last decade. Additionally, we summarize the increasing anecdotal evidence on the influence of the level of quality management on a firm's revenue and costs (Section 1.2). Using this background, we develop assumptions and notations (Section 1.3) for a framework for analysis of firm behavior under three different quality management systems: voluntary, quasi-voluntary, and mandatory. We also take into account differences between countries' liability systems and show how the rule of strict liability, as prevalent in the U.S., as opposed to the rule of negligence (U.K.) influences the adoption of quality management systems (Section 1.4). The results of our model can be evaluated with the evidence from the literature review.

2. Literature Review

2.1 Quality

When we speak of quality, it is not clear whether everyone means the same thing. Webster's New World Dictionary (1976) alone gives nine definitions. Among those is the one probably most think of

when they talk about the quality of a certain good: the degree of excellence which a thing possesses. However, another, much broader definition is any of the features that make something what it is; characteristic element; attribute. The latter is usually the meaning when quality is under investigation in the economics, consumer studies, and business administration literature.

The formal introduction of quality into the language of economics was by Lancaster (1966). Instead of assuming that a good is a good, he asserts that a good consists of attributes. Those attributes can be the nutritional as well as the aesthetic characteristics[1] or food safety, value/function, sensory/organoleptic, or process characteristics (Hooker and Caswell 1995) of a meal. For examples of the major attributes of food products see Table A.1. This approach states that every good has more than one attribute. Thus, consumption of a good is really consumption of one good with several characteristics or, in economic terms, joint outputs. This leads to Lancaster's assumption that it is not the good itself from which consumers derive utility, but that utility is derived from the attributes a product possesses. The quality of a product, as we will use the term in this context, is therefore the joint output of all the attributes of that product.

The level of quality of a product can then be determined by measuring whether the attributes are what they are defined to be. That is, if a British firm orders pencils from an Italian firm and the contract spells out that the pencils must comply with current U.K. legislation, it can be checked whether all the attributes of the pencils comply with the legislation. In the case described by Fidler (1990), the pencils contain more than the permitted level of heavy metals in the paint coating and are thus, in our language, of low quality. In this example, we assume that all attributes can be scientifically defined and measured. However, there is rarely complete and perfect information on a product. That is, a consumer knows the color of a tomato by looking at it, she can smell it, and after buying and consuming it, she knows the taste of it and how convenient it was to prepare, but she does not know whether the tomato contained any pesticide residues or was irradiated.

This notion that there are different levels of information on attributes has been captured by four authors: Stigler (1961; 1962), Nelson (1970), and Darby and Karni (1973). Stigler introduced the idea of search attributes. In the example, information on color and smell of the tomato can be gathered by inspecting the tomato on the grocer's shelf. Thus, search attributes, as more narrowly defined by Nelson, are attributes which the buyer inspects through observation prior to purchasing the good. The second set

[1]We use properties, characteristics, and attributes interchangeably.

of attributes has been called experience attributes (Nelson 1970). Experience attributes can only be identified after purchase and consumption (e.g., taste, convenience of preparation). The third set of attributes, credence attributes, was explored by Darby and Karni. Credence attributes cannot be judged independently by the buyer even after consumption. In the case of a tomato, it is not feasible for a consumer to test every tomato for pesticide residues or irradiation. At most, the consumer can have a belief about those attributes of a product. Nevertheless, the distinction between the three types of attributes is relative. It may be infeasible for a consumer to test the products bought for pesticide residues or irradiation, making these credence attributes for the consumer. However, companies may find it worthwhile to test for pesticide residues making them a search attribute to the company.

There are ways to convert credence attributes into search attributes even for consumers. Consumers can use extrinsic measurement indicators and extrinsic cues (see Table A.1). Quality management systems are an extrinsic measurement indicator. They assure buyers that a firm works to a certain, pre-specified standard and that quality will not be lower than this standard. Another extrinsic measurement indicator is certification of a product to a certain standard (e.g., organic). It indicates to the buyer that the product has no pesticide residues. Thus, the credence attribute (food safety) has become a search attribute. Extrinsic cues are price, brand name of the product, store name, informational advertisements (e.g., on irradiation), and others (Steenkamp 1987). Using these extrinsic cues, a customer is able to form a belief about the quality of the product, i.e., the level of its (intrinsic) attributes.

Depending on the degree of imperfect information in the market, firms are able to discriminate between buyers and exert market power. As long as a product is mainly sold based on price, the market for this product is most likely competitive because prices are searchable and comparable. However, if the attributes of nutritional content or the risk of foodborne illness are very important to consumers, markets may be imperfect because the firms' claims regarding these attributes are difficult to verify. Governments may choose to intervene in these markets to deter price discrimination and market power exertion. Another reason for intervention is the gain in benefits to society from a safer and more nutritious food supply. A safer food supply leads to better health, protects consumers against external health hazards, and helps rehabilitate health in case of damage (Caswell 1998). External health hazards are, among others, deaths and illnesses from foodborne diseases. For example, the risk of being infected with salmonellosis is about 14.93 in 100,000 people in the U.S. and of dying from salmonellosis is about 0.37 in 100,000 per year. The risk of being infected by *E. coli* 0157:H7 is 5.6 in 100,000 people in the U.S.

and of dying from *E. coli* 0157:H7 is 0.86 in 100,000 people per year.[2] Governments may intervene by requiring mandatory nutritional labeling or introducing minimum quality (input, process, or product performance) standards to, for example, prevent foodborne diseases from pathogens like *Salmonella*, *Trichinella spiralis*, or *Staphylococcus aureus*. This is called *ex ante* regulation. *Ex post* regulation such as tort law is another form of government intervention (Beales, Craswell, and Salop 1981). A caveat is that *ex ante* and *ex post* government regulation is often only an imperfect instrument especially in the case of foodborne diseases. Minimum quality standards may not capture all foodborne pathogens, and many illnesses caused by foodborne pathogens are not identified as food poisoning. Even if they are correctly identified, it is often hard to prove which product caused the food poisoning. Thus, there is only a very small probability that firms actually get sued for liability (Buzby and Frenzen Forthcoming).

Consumer pressure may also improve the quality offered in markets for credence attributes. Consumer awareness regarding the safety attributes of food products has been heightened by recent outbreaks of *Salmonella* and *E. coli* O157:H7 in the U.K. and the U.S. as well as the Bovine Spongiform Encephalopathy (BSE) scare in Europe and the Coke lapses in Belgium and France in the summer of 1999. Grocery stores are answering the demand for increased quality by introducing quality management systems for their warehouses and stores. Additionally, grocery stores are requiring their suppliers to implement quality management systems to ensure a certain minimum standard throughout the supply chain. A supply chain in the food industry, in general, reaches from the input supplier of the farmer, to the farmer, through several processors and storage and handling locations, and via transportation systems to the retailer or restaurant, and finally to the consumer. The quality of a good can be influenced at each of the links.

An example of the influence of consumer demand is the approach of the British retailer Sainsbury which sells its own-brand labeled products as high-quality products. To back up this claim, Sainsbury actively developed supply chain management, advising the farmers and growers it buys from on what to grow, how to grow it, how much to grow, and when to supply it. Sainsbury also requires that its suppliers meet certain quality standards regarding harvesting, packing, handling, and transport of the products, which influence hygiene, refrigeration of stores and transport, and efficient handling. Finally, it assures the quality of its products by regularly auditing its suppliers' facilities for compliance to the agreed-upon standards (Love 1993). Another example is the increasing awareness of consumers regarding the impact

[2]This data comes from the Internet site of the Centers for Disease Control and Prevention, www.cdc.gov.

of industrial agriculture on the environment and health (e.g., increased cancer risk from consumption of food with pesticide residues) (Bockstael 1984) which led to a remarkable growth in the demand for organic products in all developed countries.

2.2 Quality Management Systems

The quality of a product can be influenced by use of quality management systems (QMS) in the production and processing process. In general, quality management systems seek to control the quality of a product as determined by the array of individual (search, experience, and credence) attributes the product possesses, with a goal of meeting agreed-upon requirements. One formal definition is: "All activities of the overall management function that determine the quality policy, objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance and quality improvement within the quality system" (ISO 1996, p. 1). Thus, QMS are implemented by firms within the supply chain to deliver products of pre-specified quality to consumers.

Most firms have some form of quality management incorporated into their production and processing without necessarily calling it quality management or without formalizing the related procedures. For example, a television set producer always checks at the end of the production line whether the television set's colors are correct, and the volume and other controls work. If something does not work satisfactorily, the television set is sent back to be reworked, after which it will be checked again, or to be scraped. However, every firm has a different approach to quality management and sets different quality standards. Thus, when comparing television sets, consumers cannot know whether the quality standards are the same between different brands. They will not be able to check all quality claims by different producers, although reputation or *Consumers Report* may provide information the consumer would otherwise not have. The same is true for relations between firms. If the televison set producer relies on a supplier for the picture tube, only inspection of the supplier's production plant and the assembly of the picture tube will ensure that the tube meets the quality standard claimed. This is the reason many firms regularly audit the production plants of their suppliers.

The introduction of a formal quality management system can help both producer and buyer in determining the actual quality of the product produced. Additional verification of the quality level can be obtained through third-party certification of the quality management system. Third-party certification by accreditation agencies, trade organizations, or national assurance systems can provide credibility to

firms' claims. Examples of national farm level assurance systems include Scottish Borders Traceability and Assurance Group (TAG) and Farm Assured British Pigs; of proprietary quality assurance systems, those of large retail food chains in the U.K. such as Sainsbury; and for private international quality assurance standards, ISO 9000. These QMS use a certifiable standard as a way to assure that the quality of a product delivered is as contracted.

The above examples can be mainly categorized as voluntary QMS. That is, companies decide to implement the QMS because they think the internal benefits of implementation will outweigh the costs. They may also introduce QMS because they expect to attain greater market share or better prices for their quality-certified products. However, voluntary proprietary quality assurance systems may turn into quasi-voluntary systems. In the U.K., for example, ten retail food chains dominate the market with 60% of all sales (Henson and Northen 1998). Not implementing the QMS demanded by these chains may leave a firm without its major buyers. This turns the implementation of QMS into a *de facto* requirement to retain business. When Bredahl, Holleran, and Zaibet (1997) surveyed 377 firms in the U.K. food industry in 1996 on whether ISO 9000 was standard business practice, 61% replied no. However, 39% replied yes, especially in areas of the food and drink sector such as ingredients and beverages suggesting a trend toward QMS becoming standard business practice (or, quasi-voluntary). Finally, mandatory QMS exist as *ex ante* regulation. They are an integral part of the food system "and, in conjunction with input, process, and performance standards for food products, significantly influence how markets for food quality function and develop" (Caswell and Mojduszka 1996, p. 1248). For example, in the U.S., Hazard Analysis and Critical Control Points (HACCP) systems were mandated for the seafood industry in 1995, with full implementation to take place by December 1997 (Colatore and Caswell 1999).

HACCP started in the 1960s as a voluntary system, but was mandated by the U.S. government for the meat, poultry, and seafood processing sector in the late 1990s. It is primarily concerned with the control of foodborne risks, especially pathogens, i.e., with food safety related attributes (Caswell and Hooker 1996). Under the HACCP system, the product's quality is not investigated at the end of the production line (which is often impractical), but at Critical Control Points (CCPs) where the quality of the product could be negatively affected. One of the features of HACCP is that acceptable limits for control points are identified and statistical methods are used to identify when the limits are violated (Mazzocco 1996). Certification is usually achieved through government audits when regulation requires HACCP.

HACCP implementation consists of incorporation of seven basic principles into the production process: conduct a hazard analysis; identify the CCPs of each specific production process; establish Critical

Limits (CLs) for preventive measures associated with each identified CCP; establish CCP monitoring requirements; establish corrective actions to be taken when monitoring shows that a CL has been exceeded; establish effective record keeping procedures that document the entire HACCP system; and establish supervising procedures to verify that the HACCP system is working correctly (Colatore and Caswell 1999). For example, Colatore and Caswell (1999) identify two safety-related hazards in the breaded fish industry: microbiological growth in batter and metal inclusion. The first can be controlled by carefully monitoring the temperature of the batter at each stage of production, while the latter can be detected by using a metal detection device at the appropriate CCPs.

ISO 9000 is another important example of quality management systems. It is a process standard and mostly voluntary. It developed from the British BS 5750 (1979), which was designed for the engineering industries but can be used in any industry. ISO 9000 is a summary term for a series of five documents published by the independent International Organization for Standardization (ISO) based in Geneva, Switzerland. It is reviewed every five years to ensure that it reflects current technology (Surak and Simpson 1994). By 1996 over 95,000 companies in a wide range of industries were registered worldwide for all of the ISO 9000 systems, with over 45,000 of those in the U.K. and approximately 10,000 in the U.S. (Holleran and Bredahl 1997). Companies in continental Europe have been slower in adopting quality management systems, e.g., in Italy only 269 firms were certified by the end of 1997. However, Canavari, Regazzi, and Spadoni (1998) found that of the 226 production facilities they surveyed in the Italian food system, 65% saw quality management systems as useful and many were interested in their implementation. ISO 9000 does not necessarily ensure product quality/safety unlike HACCP. Thus, HACCP can further enhance company QMS approaches like ISO 9000 by scientifically determining where food safety problems are likely to occur or get their start because it is aimed at ensuring product quality/safety.

The following areas have to be addressed when implementing ISO 9000: management responsibility; quality system; contract review; design control; document control; purchasing; purchaser supplied product; product identification and traceability; process control; inspection and testing; inspection, measuring and testing equipment; inspection and test status; control of non-conforming product; corrective action; handling, storage, packaging and delivery; quality records; internal quality audits; training; servicing; and statistical techniques (ISO 1994). These 20 clauses have to all be implemented when a firm wants to be certified to ISO 9001. ISO 9002 excludes the clause 'design control' and ISO 9003 is "the least restrictive system, intended for operations that demonstrate conformance only

via final inspection and testing" (Hooker and Caswell 1998, p. 7). Internal and external audits ensure proper implementation, leading to the recommendation of the firm for third-party certification. After the initial certification, external audits are conducted at certain time intervals to ensure that certification can be maintained. Often, the third-party certifiers are themselves accredited by national governmental agencies, which in the European Union is standardized by EN 45012 (Silcock 1992). However, the level of quality is defined by the company itself. Thus, implementation of ISO 9000 does not ensure 100% first quality goods (Stringer 1994).

2.3 Costs and Benefits of Quality Management Systems

In an earlier section, we mentioned the benefits for society when government acts to mandate QMS to reduce foodborne illness. In this section, we focus on the benefits and costs associated with the implementation of quality management systems solely in terms of the profit-maximizing firm. That is, firms implement quality management systems to manage different attributes of their products to meet quality standards they have agreed upon with buyers and to reap other benefits. These benefits of implementation have to be weighted against the costs incurred in producing under a QMS.

Hooker and Caswell (1998) state that a firm has four incentives to introduce a quality management system: to promote *confidence* in the firm's ability *consistently* to offer a high quality good and thus fulfill its *contractual* requirements and install a *competitive* advantage for future transactions. This points to external benefits from implementing QMS: some firms are able to charge price premia for a consistently high quality good. Others hope to attract more buyers through the creation of consumer confidence, reputation as a preferred supplier, or a marketing edge with a registered supplier status. Additionally, the introduction of QMS often leads to enhanced relationships with customers and suppliers which could also lead to increased sales and thus an increased market share (Wenmoth and Dobbin 1994). However, the other side of the coin is potential costs when QMS is not implemented, especially under a quasi-voluntary regime. These may include loss of market share, reputation, brand capital, or business (Irvine 1991).

Internal benefits of QMS are manifold. They are mostly related to decreases in production costs in such areas as raw material inspection if the supplier also has QMS in production and outbound logistics; materials specification; raw materials inventory; and process variability along the channel. Firms claim that implementation of QMS leads to process simplification and thus decreased cost (Mazzocco 1996). Sources of decreased costs reported by firms include: less rework; less waste; fewer customer returns; fewer

warranty claims; easier problem determination; less walk-through's and inspection; less unnecessary maintenance; less excessive overtime; and fewer second-party audits. Further benefits, not related directly to production, include decreases in product liability premia because of decreased risk of contamination in the product; fewer customer complaints; better response times; better data for decisions; decreasing costs of marketing/sales and after-sale service costs of supplying firms; efficiencies due to clearly defined responsibilities; employee benefits in terms of increased job satisfaction, motivation, co-operation, performance and pride in doing a job right first time; and improved internal communications (Irvine 1991; Wenmoth and Dobbin 1994).

However, QMS implementation is not costless. The costs associated with the introduction or systematization of quality management systems are very diverse. They include senior management and staff time in generating procedures; setting up, designing, implementing, and maintaining a QMS; training of personnel; recording; testing; new equipment; calibration; inspection; internal audits; consultant's fees; and last, but not least, registration fees if the QMS is certified by a third-party. However, Colatore and Caswell (1999) report that the average total cost of mandatory HACCP adoption in the first year for eight breaded fish processing companies in Massachusetts was $169,000, representing an increase of only 0.25% of their annual total cost. These costs included: time and cost of plan design; cost of training; cost of control and record-keeping; review cost; sanitation cost; and validation cost. Zaibet and Bredahl's (1997) study also suggests that the costs of implementation are quite small. They interviewed four small- and medium-sized firms in the U.K. and found that all firms indicated that the cost was not a constraint or concern in adoption.

There are many studies which show that the benefits of QMS implementation may actually outweigh the costs. Lang (1995) and Pallett (1994) provide anecdotal evidence. Lang describes the process of ISO 9000 implementation at a Sandoz Nutrition plant, while Pallett implemented ISO 9000 at two of the smaller manufacturing locations of the Rowntree Mackintosh company. Both report that the "implementation required a considerable amount of time, money, resources, and commitment ... (but that) ... the systematic and structured approach needed to achieve ISO 9000 certification helped the company to identify the best way of ensuring product quality. The effectiveness of existing procedures was evaluated and improvements made where necessary" (Pallett 1994, p. 62). Lang adds that "in the months since certification ... savings in one area alone -- materials held back because of questionable quality -- have already equaled the budget allocation for certification" (1995, p. SR 25). Golomski (1994, p. 58) gives another example for a 26-person company: "ISO 9000 registration brought the following

benefits: (1) a reduction of 20% in product liability premiums; (2) a reduction in rework, scrap, and late shipments by 15%; (3) and an increase in business of 30%. These results were unforeseen, but the president believed that spending approximately $ 75,000 on ISO 9000 was the right thing to do. He got far more than his money back within two years."

Mandatory versus voluntary implementation may decrease cost savings. It is assumed that implementation of mandatory QMS is usually more expensive than for voluntary or quasi-voluntary QMS because the firm in the latter case is able to choose the QMS that best fits its production. But even in the case of mandatory implementation, as reported by Colatore and Caswell (1999), the introduction of HACCP actually decreased the validation costs such that the average net total cost in the first year was $113,505, or, a 0.17% increase in annual total cost.

Besides production costs, firms incur transaction costs. These were identified by Coase (1937) and are defined to occur whenever a firm deals/transacts with the 'outside' world. For example, transaction costs occur whenever a firm is searching for a supplier, enters into contract negotiations, and closes a contract with a supplier. Adapting this notion of costs to the supply chain relationships of beef processors in the U.K., Hobbs (1996) identified three main subsets of transaction costs: information, negotiation, and monitoring (or enforcement) costs. Information costs arise prior to the transaction and include the search for information about products, quality, prices, inputs, and buyers or suppliers. Negotiation costs are the costs of physically carrying out the transaction and may include commission costs, the costs of physically negotiating the terms of an exchange, and the costs of formally drawing up contracts (Hobbs 1997). Finally, monitoring or enforcement costs arise after a transaction. It may be necessary to monitor the quality of goods from a supplier or to monitor the behavior of a supplier (or buyer) to ensure compliance with all preagreed terms of the transaction. The costs of seeking restitution when a contract is broken are also considered to be monitoring costs (Hobbs 1996).

Hobbs surveyed U.K. beef processing firms using conjoint analysis to measure transaction costs and finds that the beef processors organize themselves so as to minimize transaction costs. Frank and Henderson (1992) measure transaction costs in the U.S. food industries. Using a vertical coordination index, they find that an increase in transaction cost leads to more vertical coordination in the industry. Henson and Northen (1998) give examples of transaction costs associated with food safety controls in the supply of retailer own-branded products. They relate information transaction costs to approval audits of a firm; negotiation costs are identified with product testing, auditing of ingredient suppliers, and reporting procedures; and monitoring and enforcement costs are associated with routine product

inspection, routine audits, product surveillance, complaint systems, and penalty systems. The implementation of quality management systems throughout the supply chain can help to reduce transaction costs. Examples are the reduction of product procurement costs and the reduction of perceived risk of product failure (Henson and Northen 1998).

We mentioned above that governments may choose to intervene in markets with *ex post* regulation. We also reported that after implementing a QMS like ISO 9000 firms pay less in tort liability premia. Thus, product liability is an important aspect of the decision making process of a firm. It may include the probability of paying damages in case of a lawsuit, the amount of the potential litigation costs, and any negative impacts to the firm's reputation and sales (Caswell and Johnson 1991). In the U.K., after passage of the Food Safety Act in 1990, producers, importers, processors, and food retailers are required to verify the safety of the inputs and outputs of their business. A guarantee from an ingredient supplier or from a foreign food processor is no longer acceptable as evidence of *due diligence* on the part of the U.K. food firms. However, verification can be provided by implementing an adequate quality management system such as ISO 9000 and HACCP. A further incentive to introduce a QMS is the General Hygiene Act which was activated in the U.K. in 1995. It requires all food businesses to adopt a risk management tool, such as HACCP. Under a tort system of due diligence, the defendant is not found guilty for the failure of its product, if it can establish that an effective system to avoid such a failure was in place and if it can prove, through, for example, record keeping, that the system was being observed at the time of the incident. QMS provide an effective system as well as the necessary record keeping.

In the U.S., producers of consumer goods are generally held to a rule of strict liability under which the manufacturer is "liable for injuries caused by defective products even when quality control was adequate and the manufacturer was not at fault" (Cooter and Ulen 1988). Thus, the implementation of QMS is not a defense when a firm is held liable for damages. However, stringent implementation of a QMS like HACCP may protect a company from damages occurring because the risk probability decreases. Additionally, Caswell and Henson (1997) point out that in the U.S. the due diligence defense comes into effect when companies sue each other along the supply chain.

Finally, not only national legislation influences firms' behavior. As soon as a firm participates in international trade, it will be held liable to the standards of its own country as well as the country where it sells its products. This may mean, for example, for U.S. firms that the implementation of ISO 9000 and/or HACCP will be necessary for access to the European agricultural/food market.

3. Model Assumptions and Notations

The previous sections provided a background on how we define quality, what quality management systems are, what the costs and benefits of implementing them are, especially when transaction costs and product liability are considered, and on the influence of imperfect competition. Here, we develop a model that helps to explain the above phenomena by describing the circumstances under which the ith firm decides to increase its level of quality management and what the consequences are of the implementation. We specifically focus on the relationship between firms within the supply chain, that is, we are not explicitly modeling the interaction between firms and consumers. However, the consumer can be seen as the last link in the supply chain and thus the model implicitly also describes the relationship between firms and consumers. We allow for six different cases. We distinguish between two sorts of tort liability, strict liability and rule of negligence, and three forms of implementation of quality management systems, voluntary, quasi-voluntary, and mandatory.

3.1 Quality and Quality Management Systems

Many models exist that explain firm behavior when the good in question is a search or experience good or most of a good's attributes are search or experience attributes (Stiglitz 1989; Tirole 1988, Ch. 7). However, to our knowledge, there is only one article (Segerson 1999) that models firm behavior when the good produced is a credence product or most of its attributes are credence attributes. Credence attributes are costly to measure and may, in fact, be too costly to be measured. Incentives, market forces, and regulation influence whether the attributes are perceived as too costly to be measured by a firm. However, there is a market for the measurement of certain credence attributes. For example, in 1993, 700 people took ill and 4 small children died after consuming Jack-in-the-Box hamburgers contaminated with *E. coli* O157:H7 (foodborne pathogens are generally credence attributes of hamburgers). Consumers became ill because they purchased hamburgers which were not cooked thoroughly enough to eliminate potential foodborne diseases. Afterwards, Jack in the Box found that the hamburgers were already contaminated when they arrived at their franchises. Thus, a firm's probability of delivering safe products to their customers is also influenced by the quality their suppliers delivered. Consequently, Jack-in-the-Box's suppliers went to great lengths to ensure that *E. coli* O157:H7 is not being introduced into the hamburgers in their production lines. However, direct measurement of *E. coli* is costly. Thus, the producers in turn required assurances from upstream firms that the product they receive is not

contaminated. Additionally, the producers audit the upstream firms to ensure that they met the agreed-upon safety standards and implement stricter quality management systems.

We define quality as meeting agreed-upon standards, where ρ^i is the rate of success in meeting the standard. However, firms usually are concerned about the failure rate. We define the probability of failure of the ith firms' product as $\theta^i = 1 - \rho^i$, which lies between zero, no failures, and one, a failure is certain, and is not directly observable. Because θ^i is not directly observable, firms use as an indicator for the rate of failure the level of quality management in the ith firm, s^i.

Quality management systems can be implemented either voluntarily, v, or quasi-voluntarily, q, or can be mandated, m. We will examine each of the three cases. In general, assume any quality management system, s_v, s_q, or s_m requires more effort than not having a management system or having a status quo system ($s = 0$). For example, ground beef producers usually check their product's color and smell to find obvious examples of unacceptable quality. However, s can grow continuously and could include sophisticated systems like ISO 9000, HACCP, or TAG, which have been audited or even certified to a specific standard. It can be rather costly for buyers to check the suppliers' quality management. Audits or onsite inspectors are common. Thus, in these cases, s is not costlessly observable. However, when the suppliers' quality management system has been certified to a specific standard by a third-party, we can assume that the costs in observing the level of quality management decrease because the certifier, for example, now conducts the audits for which the supplier has to pay.

Here, we simplify the idea of a supply chain by talking about only three firms in the chain, the upstream firm, u; the investigated firm, i; and the downstream firm, d. Additionally, we assume that just one unit of product passes through the supply chain. Then we can define the probability of failure of the uth firm's product as dependent on the level of its quality management system, s^u. The probability of failure, $\theta^u(s^u)$, decreases the higher the level of quality management. However, it decreases at a decreasing rate. This means that the product's probability of failure decreases slower if an already high level of quality management system is further increased, ($\theta^u_{s^u} < 0, \theta^u_{s^u s^u} > 0$). The investigated firm's rate of product failure, θ^i, is also indicated and influenced by the level of its own quality management system, s^i. That is, the ith firm's probability of failure decreases at a decreasing rate when increasing its own quality management system. However, as shown in the Jack-in-the-Box case, the probability of failure for the ith firm's products is also influenced by its supplier's probability of failure. Thus, we assume that the ith firm's probability of failure, $\theta^i(\theta^u(s^u), s^i)$, increases at an increasing rate with an increasing level of the upstream firm's failure rate. Thus, $\theta^i_{s^i} < 0, \theta^i_{s^i s^i} > 0, \theta^i_{\theta^u} > 0, \theta^i_{\theta^u \theta^u} > 0$, and $\theta^i_{s^i \theta^u} < 0$, where the

last term means that given that the ith firm's probability of failure decreases with an increasing QMS, a rise in the uth firm's probability of failure will slow down this decrease. We define the probability of failure of the downstream firm as being dependent on its own quality management system, s^d, and of its supplier's, the ith firm's, probability of failure. θ^d is thus a function of $\theta^d(\theta^i(\theta^u(s^u), s^i), s^d)$. As for the two other firms, the dth firm's probability of failure decreases when its own quality management system increases, $\theta^d_{s^d} < 0$, but at a decreasing rate, $\theta^d_{s^d s^d} > 0$ and it increases at an increasing rate with increasing failure rates of its supplier, $\theta^d_{\theta^i} > 0, \theta^d_{\theta^i\theta^i} > 0$. Finally, given that the dth firm's failure rate increases with an increasing failure rate of the ith firm's product, an increase in the dth firm's quality management system will slow down this increase by, for example, detecting many of the low quality products of the ith firm, when they are delivered, $\theta^d_{\theta^i s^d} < 0$.

3.2 Benefits of Quality Management Systems

There is evidence that consumers and firms are willing to pay more for safer food products (Shin et al. 1992) and that firms implement quality management systems to ensure that they will be able to compete in a market that has a demand for safer products or out of fear of losing business (Bredahl, Holleran, and Zaibet 1997). Here, we employ a revenue term, r^i, which is a function of the rate of the ith firm's product failure and thus is in turn a function of the level of its quality management, $r^i(\theta^i(\theta^u(s^u), s^i))$. We assume that the ith firm's revenue decreases when the failure rate increases, either because the firm has to charge lower prices, or its market share decreases, or both. This effect increases with increasing failure of its product. Thus, $r^i_{\theta^i} < 0$ and $r^i_{\theta^i\theta^i} < 0$. These are assumptions we can only maintain in an industry like the food industry and within the food industry for credence attributes that are directly related to people's health. It has been well documented that for many products there is a market for low quality as well as high quality. If a, say, television producer looks for a supplier of picture tubes, then it may choose the cheapest or the one who provides the best quality, or a mixture of both. If it chooses the cheapest supplier for picture tubes, it probably perceives a higher probability of failure, i.e., the delivered picture tubes may be defective more often than those from a more expensive supplier. However, it is willing to take this risk. We assume here, that this is not true for products which have food safety attributes. As shown in the literature review, there is ample evidence that consumers are demanding safer and safer foods. Thus, we assume that a lower probability of failure is better.

3.3 Costs of Quality Management Systems

The costs the ith firm incurs when producing its product are also influenced by the rate of failure. We differentiate between three types of costs: production, transaction, and liability costs.

3.3.1 Production Costs

We assume that the ith firm only incurs variable production costs, C^i. Variable production costs are directly dependent on the level of quality management implemented. That is, in order to implement a quality management system, a firm usually incurs costs of new equipment, training personnel, or record keeping which increase the more rigorous the QMS is. To attain a very high level of quality management, the ith firm will have to increase its efforts even more. Thus, we assume that the ith firm's costs increase with an increasing QMS at an increasing rate, $C^i_{s^i} > 0$ and $C^i_{s^i s^i} > 0$.

Various authors (Golomski 1994; Irvine 1991; Lang 1995; Mazzocco 1996; Wenmoth and Dobbin 1994) report that an increasing level of quality management in a firm, by decreasing the failure rate of the product, decreases its variable production costs because of, for example, less waste or less rework. However, there is only so much rework that can be saved, thus we assume that production costs, $C^i(\theta^i(\theta^u(s^u), s^i), s^i)$, decrease with a lower probability of failure at a decreasing rate, $C^i_{\theta^i} > 0$ and $C^i_{\theta^i\theta^i} < 0$.

3.3.2 Transaction Costs

Transaction costs, T, include information costs, negotiation costs, and monitoring (or enforcement) costs. We assume that they are not dependent of quantity. However, they are dependent on the level of the ith firm's as well as its supplier's quality management, $T(s^i, s^u)$. Information costs, such as the search for quality increase with the ith firm's increasing quality management, because a higher standard in the ith firm's production requires a higher standard in its inputs. The search for information becomes more important and intricate. The same is true for negotiation costs. For example, the costs of physically negotiating the terms of an exchange and of formally drawing up contracts are higher when the inputs are held to higher standards because the contracts will be more specific. Monitoring and enforcement costs also increase because, for example, product surveillance or routine product inspection become more prevalent. Thus, we assume that the ith firm's transaction costs increase at decreasing rate when it increases its quality management, $T^i_{s^i} > 0$ and $T^i_{s^i s^i} < 0$.

Additionally, we assume that an increase in quality management by the upstream firm can have the opposite effect. The information, negotiation, and monitoring costs for the ith firm may decrease at

a decreasing rate the higher the s_u. For example, the U.K. government sends every interested party a CD-ROM with the names and addresses of all ISO 9000 certified suppliers for a nominal fee, i.e., product procurement costs are reduced. Additionally, if the upstream firm's QMS is certified by a third-party, audits are not necessary or can be conducted less often because the supplier has already been audited by the certifier. Thus, $T^i_{s_u} < 0, T^i_{s_u s_u} > 0$, and $T^i_{s_i s_u} < 0$. The last term is based on the assumption that better quality management in upstream firms leads to decreasing costs of raw materials inspection, costs of materials specification, and costs of raw materials inventory for the ith firm (Mazzocco 1996).

3.3.3 Product Liability

Product liability, L, is an important factor in the decision-making process for companies. We assume that liability is a constant, positive amount which has to be paid if the firm is detected as the place where the product failure occurred. Others, for example (Segerson 1999), define liability as the expected loss as a result of product failure. Such loss may include the probability of paying damages, the amount of the potential litigation costs, and any negative impacts to the firm's reputation and sales. However, to keep the model simple, we assume a constant.

However, we have to distinguish between product liability under the rule of negligence and under strict liability. Under strict liability, as prevalent in the U.S., firms can be held accountable for the failure of their product even with the most sophisticated quality management system in place and with records proving that the quality management system was operating correctly. On the other hand, under the rule of negligence, as in the U.K., the level of quality management system plays a crucial role in determining whether a firm can be held accountable for the product's failure. That is, if a firm can prove, with the help of its records, that it complied with every measure deemed crucial to avoid the product's failure, the firm will not be held liable. Thus, if the level of quality management system, s^i, is lower than the due diligence standard, $\bar{s}^i$, the ith firm is held accountable for its product's failure. However, if $s_i \geq \bar{s}_i$, the firm will not have to pay liability under the rule of negligence.

Independent of the tort law in place, the probability that a firm is actually sued is relatively low (Buzby and Frenzen Forthcoming; Viscusi 1998). Thus, the ith firm's decision-making process will be influenced by the likelihood of being held liable. We call this probability, β^i, which lies between zero and one. It is dependent on the probability of product failure. That is, the higher the probability of failure, the more likely is it that the ith firm will be held liable for that failure. This occurs at a decreasing rate as a large amount of failing products points directly to the ith firm, $\beta^i_{\theta^i} > 0$ and $\beta^i_{\theta^i\theta^i} < 0$. However,

the probability of being held liable is also a function of the downstream firm's rate of failure, $\beta^i(\theta^i(\theta^u(s^u), s^i), \theta^d(\theta^i(\theta^u(s^u), s^i), s^d))$. The higher the failure rate of the downstream firm's product, the more likely a failure is to occur and to be detected and the ith firm is held accountable at a decreasing level, $\beta^i_{\theta^d} > 0, \beta^i_{\theta^d\theta^d} < 0$, and $\beta^i_{\theta^i\theta^d} > 0$. The last term states that we assume that an increased rate of failure of the ith firm will intensify this effect.

4. A Model of the Implementation of Quality Management Systems

1.4.1 Voluntary Quality Management Systems

When a firm considers implementing a voluntary quality management system, it weighs the benefits against the costs in choosing the level of quality management which maximizes its profit. Thus, the ith firm decides on the level of voluntary quality management considering the following profit-maximizing function which we assume to be concave in s^i:

$$\max_{s^i} \pi^i = r(\theta^i(\theta^u(s^u), s^i)) - C(\theta^i(\theta^u(s^u), s^i), s^i) - T(s^i, s^u) - \beta^i(\theta^i(\theta^u(s^u), s^i), \theta^d(\theta^i(\theta^u(s^u), s^i), s^d)L. \tag{1.1}$$

Equation (1.1) exemplifies the decision-making process of a firm under the rule of strict liability. From the first-order condition we know that the optimal level of quality management system, s^{i*}, is the level at which marginal benefits equal marginal costs:

$$\frac{\partial r^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i} - \frac{\partial C^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i} - \frac{\partial \beta^i}{\partial \theta^d}\frac{\partial \theta^d}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i}L - \frac{\partial \beta^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i}L = \frac{\partial C^i}{\partial s^i} + \frac{\partial T^i}{\partial s^i}. \tag{1.2}$$

The first term on the left-hand side is the marginal benefit of a lower probability of failure rate. The second term relates to the savings in variable production costs due to higher quality management, while the last two terms are the marginal benefits of lower liability. A higher QMS for the ith firm decreases its rate of failure as well as the failure rate of the dth firm, thus decreasing the probability of being held liable. The marginal costs are comprised of two parts: marginal costs due to higher quality management and marginal transaction costs due to an increase in quality management.

Because the ith firm produces within a supply chain, its optimal level of quality management, s^{i*}, is also influenced by the level of quality management of the upstream firm, s^u, and of the downstream

firm, s^d. Comparative statics suggests that an increase in the upstream firm's quality management decreases the ith firm's marginal cost. This occurs because the uth firm's higher QMS decreases transaction costs of the ith firm and a higher QMS for the uth firm decreases its failure rate which in turn decreases the ith firm's failure rate. However, the increase in s^u has mixed influences on the ith firm's marginal benefits. The marginal benefits of the ith firm only increase with increased s^u if the effects of a first group of factors are greater than those of a second set. The first set includes: (1) the increase in revenue due to a further decrease in the ith firm's failure rate, (2) the decrease in variable costs due to a further decrease in θ^i, (3) the decrease in the probability of the ith firm being held liability due to a trigger effect of s^u on θ^d, and (4) the decrease in the probability of the ith firm being held liable due to a further decrease in θ^i. The second set of effects is (1) a slowing in the increase in revenue because of a decrease in the rate at which the ith firm's failure rate decreases, (2) a slowing in the decrease in variable cost for the same reasons, (3) an accelerating in the increase of the probability of the ith firm being held liable, (4) a decelerating of the decrease of the probability of the ith firm being held liable, and (5) a slowing in the decrease of θ^i. Therefore, if the upstream firm increases the level of its quality management and the ith firm's marginal benefits increase with an increased s^u, that is the first set of factors is greater than the second set of factors, the ith firm's optimal QMS, $s^{i*}_{s^u}$, is higher than when the uth firm does not act at all, $s^{i*}_{s^u} > s^{i*}$. If the two sets of factors are equal, the optimal level will also be higher but smaller than under the condition that the marginal benefits increase. If the first set is smaller than the second set, the optimal QMS will decrease even further and may become smaller than under the condition that the uth firm's QMS stays the same, $s^{i*}_{s^u} < s^{i*}$.

An increase in the downstream firm's QMS has a clear implication. Equation (1.2) becomes

$$\frac{\partial \pi^i}{\partial s^i \partial s^u} = - \frac{\partial \beta^i}{\partial \theta^d \partial \theta^d} \frac{\partial \theta^d}{\partial s^d} \frac{\partial \theta^d}{\partial \theta^i} \frac{\partial \theta^i}{\partial s^i} L - \frac{\partial \beta^i}{\partial \theta^d} \frac{\partial \theta^d}{\partial \theta^i \partial s^d} \frac{\partial \theta^i}{\partial s^i} L - \frac{\partial \beta^i}{\partial \theta^i \partial \theta^d} \frac{\partial \theta^d}{\partial s^d} \frac{\partial \theta^i}{\partial s^i} L, \qquad (1.3)$$

which suggests that the marginal benefits of the ith firm decrease with an increasing QMS of the downstream firm. Thus, the ith firm's optimal QMS is lower when the dth firm increases its QMS than when the dth firm's QMS is constant, $s^{i*}_{s^d} < s^{i*}$.

The above results are valid under strict liability as practiced in the U.S. However, if we assume that the rule of negligence is prevalent, as it is in the U.K., a firm is only held liable if it cannot prove that its production adhered to the due diligence standard, $\bar{s}$, in place. Thus, $L > 0$ if $s^i < \bar{s}^i$ and $L = 0$ if

$s^i \geq \bar{s}^i$ under the rule of negligence. If the ith firm's optimal level of QMS is smaller than the due diligence standard, $s^{i*} < \bar{s}^i$, the ith firm implements a quality management system equal to or higher than the due diligence standard if and only if:

$$\frac{\partial r^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i} - \frac{\partial C^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i} - \frac{\partial C^i}{\partial s^i} - \frac{\partial T^i}{\partial s^i} \geq \frac{\partial r^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i} - \frac{\partial C^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i} - \frac{\partial \beta^i}{\partial \theta^d}\frac{\partial \theta^d}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i}L - \frac{\partial \beta^i}{\partial \theta^i}\frac{\partial \theta^i}{\partial s^i}L. \quad (1.4)$$

This condition holds as long as the expected marginal loss as a result of product failure is greater than zero, which is by assumption true. Thus, it is in the ith firm's best interest to implement at least the due diligence standard to avoid any payments related to liability. Research discussed in Section 1.2 shows evidence of this reasoning occurring in firms. For example, the certification to ISO 9000 has dramatically increased in the U.K. since the introduction of the Food Safety Act in 1990.

4.2 Mandatory Quality Management Systems

Under quality management systems mandated by government, the level of quality management which has to be implemented by every firm in the given industry is set by *ex ante* regulation. The government can impose *ex ante* regulation in two different ways. It can impose a performance standard which prescribes the minimum level of quality, for example, bacteria counts per given weight of product. Or, it can impose a process standard, where the way a product is produced is prescribed, such as in the recent regulation requiring mandatory implementation of HACCP in the U.S. seafood and red meat industries.

There are two questions related to mandatory quality management systems. First, should the government require mandatory implementation of QMS or could the same standard be achieved in other ways? Second, if a mandatory standard is set, is there an incentive for firms to implement a standard higher than required? To describe the profit-maximization function of a firm in an environment of mandatory quality management systems, we have to make some adaptations to the assumptions of Section 1.3.

There is evidence that implementing a mandated quality management system is more expensive to firms than a voluntary system at the same level. That is, if the government imposes a process standard, it often does so with strict rules on how the standard is implemented. These rules apply to all companies

within the industry and thus lead to inefficiencies. What is best on average is often not best for a single firm. Henson and Heasman (1998) show that firms incur significant costs related to complying with regulatory requirements. Thus, we assume, that the cost of implementing a mandated QMS are higher than for a voluntary system of the same level, $C_m^i(\theta_m^i(\theta_m^u(s_m^u), s_m^i), s_m^i) > C_v^i(\theta_v^i(\theta_v^u(s_v^u), s_v^i), s_v^i)$.

Segerson (1999) refers to the positive effect of an increased QMS on revenue as public relations benefits. That is, if the ith firm voluntarily implements a higher QMS, it may be able to charge higher prices or gain market share because consumers appreciate the increased quality. Segerson further argues that under a mandatory implementation of QMS, these benefits do not accrue. Thus, we assume that under the same level of QMS, the revenue after voluntary implementation is higher than after mandatory implementation, $r_m^i(\theta_m^i(\theta_m^u(s_m^u), s_m^i)) < r_v^i(\theta_v^i(\theta_v^u(s_v^u), s_v^i))$. Finally, we assume that the probability that the government actually mandates a QMS is γ and ranges from zero to one. Given these assumptions and that the tort rule is strict liability, we can answer the question of whether mandatory requirements are necessary or the same standard can be achieved voluntarily. The regulatory standard, s_m^i, will be implemented by the ith firm voluntarily, if and only if its profit under the equivalent to the mandatory system, s_{vm}^i, is at least as high as under the otherwise chosen voluntary system, s_v^{i*}. Dropping the superscript i for ease of notation, we have:

$$r_{vm} - C_{vm} - T_{vm} - \beta_{vm} L \geq \gamma(r_m - C_m - T_m - \beta_m L) + (1-\gamma)(r_v - C_v - T_v - \beta_v L) \qquad (1.5)$$

Consider two special cases to illustrate the situation. First, assume that no *ex ante* regulation is under consideration and thus the probability of government intervention, γ, is zero. Then, equation (5) holds when $s_{vm}^* = s_v^*$, because the first-order conditions are identical. Under no threat, a quality standard equivalent to the mandatory standard is only implemented if the ith firm would have chosen that level voluntarily.

For the second case, we set γ, the probability of government intervention, equal to one. That is, it is certain that the government will step in if the firms do not increase their level of quality management to the proposed mandatory level. In this case:

$$r_{vm} - C_{vm} - T_{vm} \geq r_m - C_m - T_m \qquad (1.6)$$

Given that revenue is higher and production costs are lower under voluntary implementation, condition (1.6) always holds. Thus, the ith firm will voluntarily implement a QMS equivalent to the proposed mandatory standard. Note, that (1.6) is independent of liability because under the rule of strict liability, mandatory and voluntary implementation of QMS are not treated differently. However, this is the extreme case of certain regulation. Obviously, the level of credibility of the government's threat is key in determining when a firm is better off implementing its lower voluntary standard as in the first special case or voluntarily implementing the government's preferred standard as in the latter special case.

However, a caveat remains. We have looked at a supply chain where there is just one firm on each level. In the real world, on every level there are many firms that have incentives to free-ride on their competitors. That is, if the majority of the firms in the industry implement the proposed mandatory standard voluntarily, government is likely not to implement regulation. Thus, firms that do not implement the higher standard will have the benefit of no regulation without having the costs related to the higher standard. This problem is not analyzed here.

To answer the second question whether the ith firm has an incentive to implement a standard higher than the required one, if a mandatory standard is required, we assume that the government has enacted regulation regarding a process standard. The process standard requires all firms in an industry to implement a mandatory quality management system. This is essentially the same situation as in the section on voluntary implementation of QMS. That is, given that every firm in the industry has the same standard, is it profitable for the ith firm to offer a product with an even lower probability of failure? The results of section 1.4.1 apply here: (1) the ith firm increases its level of quality management only if the benefit of increased revenue, savings in variable production costs, and marginal benefits of lower liability payments are outweighed by the increase in transaction costs and the costs of implementing a higher level of QMS; (2) if the downstream firm increases its level of QMS, the ith firm has a disincentive to increase its quality management system; and (3) if the upstream firm increases its level of QMS, depending on this move's influence on the ith firm's marginal benefits and costs, the ith firm has an incentive to increase, hold constant, or decrease its quality management system.

We now turn to the case of a rule of negligence. To answer the above questions, we have to distinguish between two cases: (a) the mandated standard as defined by the legislature is at least as high as the due diligence standard as defined by the judiciary, and (b) the standard mandated by *ex ante* regulation is lower than the due diligence standard defined by the courts. Under case (a) we can answer the first question, whether the government should require mandatory implementation of QMS or the

same standard could be achieved in other ways, as follows. The regulatory standard, s_m^i, will be implemented by the ith firm voluntarily, if and only if its profit under the equivalent to the mandatory system, s_{vm}^i, is at least as high as under the otherwise chosen voluntary system, s_v^{i*}. Rewriting equation (1.5) and dropping the superscript i for ease of notation, we have:

$$r_{vm} - C_{vm} - T_{vm} \geq \gamma(r_m - C_m - T_m) + (1-\gamma)(r_v - C_v - T_v - \beta_v L) \qquad (1.7)$$

Because liability is not a cost factor anymore, if the ith firm implements the level of mandatory QMS voluntarily, condition (1.7) holds with a lower probability of government intervention, γ, than under the scenario of strict liability. The answer to the question, whether, if a mandatory standard is set, there is an incentive for firms to implement a standard higher than required, is the same as in section 1.4.1. That is, a firm will only implement a higher QMS voluntarily if it is profitable through, for example, higher prices or increased market share due to product differentiation.

Under case (b) where the mandated QMS is lower than the due diligence standard, $s_m^i < \bar{s}^i$, the ith firm has an incentive to implement a standard higher than the required one to avoid liability costs as shown in equation (1.4). This also suggests, regarding the second question, that firms do voluntarily implement a higher standard, at least under the circumstances of case (b).

4.3 Quasi-Voluntary Quality Management Systems

In a world in which quasi-voluntary quality management systems are prevalent, the ith firm is asked by its customer, the downstream firm, to implement a certain standard which is higher than the standard the ith firm has implemented at that point of time. This leaves the ith firm with the decision whether to implement the system to keep its only (in this extreme case) customer or to retain its current level of quality management but potentially lose its customer. We have to adjust our assumptions from section 1.4.1 for this new situation. Because the downstream firm buys from its supplier only if the quasi-voluntary standard is implemented, the revenue of the ith firm is not only dependent on the probability of product failure but also directly on the level of quality management implemented. That is, if the downstream firm requires a certain level of quality management to be implemented, then the ith firm has little choice but to implement that level. Thus, under the system of quasi-voluntary quality management, revenue is $r_q^i(\theta_q^i(\theta_q^u(s_q^u), s_q^i), s_q^i)$ which is increasing in s_q^i at a decreasing rate, $r_{s^i}^i > 0$ and $r_{s^i s^i}^i < 0$. There is evidence that the existence of a quasi-voluntary quality management systems can lead to

inefficiencies as different major buyers ask for different quality management systems (Henson and Northen 1998). Therefore, we assume that the costs of implementing a quasi-voluntary QMS are higher than for a voluntary system of the same level, $C_q^i(\theta_q^i(\theta_q^u(s_q^u), s_q^i), s_q^i) > C_v^i(\theta_v^i(\theta_v^u(s_v^u), s_v^i), s_v^i)$. Additionally, we assume that transaction costs are higher under a quasi-voluntary than under a voluntary QMS of the, given they are at the same level, $T^i(s_q^i, s_q^u) > T^i(s_v^i, s_v^u)$. The decision criterion for the ith firm on whether to implement the quasi-voluntary standard or not, becomes (dropping the superscript i for ease of notation):

$$r_q(\theta_q^i(\theta_q^u(s_q^u), s_q^i), s_q^i) - C_q - T_q - \beta_q L \geq r_v(\theta_v^i(\theta_v^u(s_v^u), s_v^i)) - C_v - T_v - \beta_v L. \qquad (1.8)$$

The potential higher production and transaction costs under the quasi-voluntary regime, seem to make the decision easy. The firm is better off not implementing the quasi-voluntary standard. However, the firm may have to implement the quasi-voluntary QMS anyway because of the threat of the loss of its customer. Without the quasi-voluntary standard, revenue will decrease dramatically leaving the ith firm little choice.

Under the rule of negligence, the same is true. However, if the quasi-voluntary QMS is at least as high as the due diligence standard, the ith firm has an additional incentive to implement the quasi-voluntary QMS as shown in section 1.4.1.

5. Conclusion

The recent trend toward implementation of voluntary, quasi-voluntary, and mandatory quality management systems in the food and other industries leads to the question of under which conditions which system is more prevalent. Quality management systems have been introduced to control search and experience, as well as credence attributes of products. We explore the implementation of QMS for the latter type, when unobservable or hard to measure attributes are important components of the relationship between firms. We analyze the conditions under which firms implement quality management systems in a simplified supply chain with one upstream, one middle, and one downstream firm, which pass along one unit of product. We assume that the probability of product failure is not directly observable. However, the level of a firm's quality management is an indicator of its product's failure rate. A higher level of quality management signals a lower probability of product failure. We incorporate knowledge on the impact of QMS use on companies from earlier studies that used surveys and

personal interviews. Our model includes the most important elements affecting a profit-maximizing firm's decision: revenue, and production, transactions, and liability costs. Since the two countries where QMS implementation has been closely studied, the U.S. and the U.K., have different legal systems, we also analyze the model under both strict liability and the rule of negligence.

The results suggest that under voluntary, quasi-voluntary, and mandatory implementation of QMS, the rule of negligence induces firms to implement a higher level of quality management than under the rule of strict liability, as long as the standard required is higher than firms would implement voluntarily. This is consistent with the growth in the implementation of high-level quality management systems in the U.K. and the slower adoption of these systems in the U.S. We also find that the relationship between firms along the supply chain is an important indicator on what level of quality management a firm will voluntarily implement. That is, an increase of the level of quality management by the downstream firm will induce the investigated firm to implement a lower level of quality management than if the downstream firm's QMS is held constant. However, the existence of quasi-voluntary quality management systems, reverses this result. The increase of the upstream firm's quality management system may have increasing, constant, or decreasing influence on the ith firm's QMS, depending on the influence of the upstream firm's actions on the ith firm's marginal benefits and costs.

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Appendix

Table 1 Intrinsic Attributes - Extrinsic Indicators and Cues

Intrinsic Quality Attributes of Food Products (Search, Experience, Credence)	**Extrinsic Quality Indicators and Cues of Food Products** (Search)
1. **Food Safety Attributes** Foodborne Pathogens Heavy Metals and Toxins Pesticide or Drug Residues Soil and Water Contaminants Food Additives, Preservatives Physical Hazards Spoilage and Botulism Irradiation and Fumigation Other	1. **Test/Measurement Indicators** Quality Management Systems Certification Records Labeling Minimum Quality Standards Occupational Licensing Other
2. **Nutrition Attributes** Calories Fat and Cholesterol Content Sodium and Minerals Carbohydrates and Fiber Content Protein Vitamins pH-Level Other	2. **Cues** Price Brand Name Manufacturer Name Store Name Packaging Advertising Country of Origin Distribution Outlet Warranty Reputation Past Purchase Experience Other Information Provided
3. **Sensory/Organoleptic Attributes** Taste and Tenderness Color Appearance/Blemishes Freshness Softness Smell/Aroma Other	
4. **Value/Function Attributes** Compositional Integrity Size Style Preparation/Convenience Package Materials Keepability Other	
5. **Process Attributes** Animal Welfare Authenticity of Process/Place of Origin Traceability Biotechnology/Biochemistry Organic/Environmental Impact Worker Safety Other	