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Agricultural Organization in an Era of Traceability

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From production to retail, information systems have become increasingly important in the agrifood system. Retailers use information systems to improve inventory management and increase efficiency in production and logistics. Innovations in agribiotechnology and food safety issues highlighted by incidences related to Starlink corn and "mad cow disease" have raised consumer concerns about their food products. In addition to food safety concerns, consumers are increasingly willing to pay premiums for nonobservable quality characteristics in their food products. This paper outlines a framework for evaluating the implications of traceability for the organization of the agricultural system and highlights potential organizational responses to traceability issues.

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From production processes to consumer demands, information systems have become increasingly important in the agrifood system. Producers and retailers use information systems to improve inventory management, reduce paperwork, and increase efficiency in production and logistics. Innovations in agribiotechnology and food safety issues highlighted by incidences related to Starlink corn and "mad cow disease" have raised consumer concerns about the sources of and inputs to their food products, and have increased political pressure from some quarters for greater regulation and information disclosure in the food system. In addition to food safety concerns, consumers are increasingly willing to pay premiums for nonobservable quality characteristics in their food products, such as organic production, "fair trade" with peasant producers, or animal-friendly production practices like free-range poultry.

The term "traceability" has become associated with the information and production systems that capture, transmit, and ensure the integrity of these varied information-based goods and processes. While traceability is a well-established characteristic of quality control systems in the general supply-chain management literature, issues of traceability in the agrifood system are relatively new in agribusiness research. In particular, there has been little attention paid to the implications of traceability for the structure of the agrifood system. Because traceability systems require and transmit greater information at various levels throughout the food chain, and because the information itself is the source of a greater share of value, it is reasonable to expect changes in the ways transactions are structured or governed.

My objective in this paper is to offer a framework for evaluating the implications of traceability for the organization of the agricultural system and to highlight potential organizational responses to traceability issues in various segments of the food system. The pa-

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per proceeds with a brief overview of the types and applications of traceability systems, followed by a conceptual framework for understanding the implications of traceability for the incentives and structure of supply transactions. I review research on the implications of different types of traceability systems in nonagricultural industries, then discuss the lessons of that research for the agrifood system.

The Role and Purpose of Traceability Systems

As noted above, the term "traceability" is used to describe a wide range of information-based tools and processes. The International Organization for Standards (ISO) defines traceability in its ISO 9000 family of standards as "the ability to trace the history, application, use and location of an item or its characteristics through recorded identification data" (Hoyle, p. 147). ISO 9000 is concerned with quality management, defined as "what the organization does to enhance customer satisfaction by meeting customer and applicable regulatory requirements and to continually improve its performance in that regard" (ISO).

The latest revisions to ISO 9000, referred to as ISO 9000:2000, place particular emphasis on performance improvement, rather than simple process implementation. Claus argues these changes make ISO 9000:2000 more relevant and appropriate for agribusinesses and food safety concerns. Although ISO 9000 focuses specifically on quality management, traceability systems afford at least three general types of benefits in food supply-chain systems: improving general supply-chain efficiency, identifying and correcting quality breakdowns in the supply chain, and marketing information-based characteristics in food products. This section briefly describes the nature of these applications and their benefits.[1]

[1] An argument could be made that there is a difference between privately ordered and publicly ordered traceability systems. Unless otherwise noted, my discussion is focused on privately ordered systems, although the organizational implications of a publicly ordered system would be similar to a privately ordered system. The primary difference may be the net value created by making such a system mandatory rather than voluntary.

Inventory Control and Supply-chain Management

One application of traceability systems is the use of inventory tracking and information systems to improve supply-chain management. Although not what most agricultural economists seem to think of when discussing traceability, this is a particularly important application at the retail level of the food chain, where inventory tracking systems play a significant role in relations between grocery chains and food processing companies. Electronic data interchange (EDI) and similar information systems allow retailers and producers to track inventory levels, record product sales and shelf duration, and automate payment to the vendor at the time of sale.

Using data from Campbell Soup Company, Cachon (1995) finds that such continuous product replenishment (CPR) strategies may reduce a grocery retailer's cost of goods sold by as much as 1%. He notes, "[in] an industry with profit margins usually less than 3%, CPR offers a major boost in profitability" (p. v). Cachon and Fisher find that CPR strategies with inventory tracking create savings by reducing the lead time required for placing orders and by reducing the batch size of orders. Similarly, Hubbard finds that information technologies that allow tracking of trucks (that is, tracing the location and use of trucking equipment) improved capacity utilization.

Such inventory traceability systems require coordinated information systems among participating members in the supply chain, often requiring a significant financial investment. For instance, when Wal-Mart moved to require vendors to use radio frequency identification (RFID) tags on their product shipments, analysts estimated vendors would incur costs of close to $1 million to implement the infrastructure and potentially tens of millions of dollars in recurring tag costs (Collins).

Identifying and Correcting Quality Failures

The ability to trace quality failures to their source is an important feature of food safety controls and one of the focal points of agricultural economics research on traceability. These are the types of traceability systems that most resemble ISO 9000 standards. Hobbs discusses two important dimensions of traceability in this regard: the ability to identify and correct problems and the ability to assign liability to responsible parties.[2] As evidenced by incidences of *Escherichia coli* contamination in meat, Starlink contamination in corn food products, or a Bovine Spongiform Encephalopathy (BSE)-infected cow, the ability to quickly trace the source of the contamination; recall other products, batches, or animals that may also be contaminated; and assure the safety of the remaining stock of food products or livestock has tremendous private and public welfare implications.

One advantage of trace-back systems is that information does not need to be as tightly integrated between stages of production as the inventory control and electronic ordering systems described above. Each participant in the value chain must maintain historic records of inputs and/or disposition of products in the event a product needs to be traced, but the information need not be shared between parties.[3] However, this also means that information does not flow between parties unless there is a problem. The information has little additional value except as insurance in the event of potential quality failures.

Hobbs' argument concerning legal liability poses both positive and negative consequences. On one hand, traceability may limit a party's potential legal liability by facilitating the identification and recall of potentially affected products or animals before greater harm (and thereby liability damages) are incurred. The ability to identify the point of failure also affords more efficient allocation of liability to the appropriate member of the supply chain. Hobbs argues that enhanced legal liability for quality failures would improve incentives to invest in more effective quality controls. However, this also suggests a potential shift in legal liability among participants in the supply chain, which means a potential change in risk exposure. Changes in exposure to uncertainty such as legal liability risk may have significant organizational or contractual consequences for the supply chain.

Marketing Information-Based Product Characteristics

The third potential use of a traceability system is to move information down the supply chain toward the customer, particularly information concerning quality traits or product attributes that are not readily identifiable by the end consumer (i.e., credence goods). Examples of credence goods in agriculture would include free-range chicken, organic or nongenetically modified (nonGM) food products, dolphin-safe tuna, and country of origin labeling (COOL). This application of traceability is what Smyth and Phillips refer to as identity preserved production and marketing (IPPM) systems.[4]

IPPMs are not new to agriculture. White corn, popcorn, waxy beans, and a host of other specialty crops have long been marketed through dedicated channels to assure integrity of the product. However, as consumers and governments demand greater information about the sources of and inputs to their food products, IPPMs have become increasingly important in major crops and food products such as soybeans, corn, beef, and pork, particularly in terms of demand for credence attri-

[2] Actually, Hobbs treats these as two distinct functions of traceability systems. However, since liability runs to the party responsible for the failure, tracing the failure to its source is tantamount to identifying the responsible party. If the nature of the failure is subject to legal sanctions, the two functions of *ex post* traceability go hand in hand.

[3] Although records need not be shared between successive stages of production in order for traceability to be available, suppliers may be required to share their records with their customers or to authenticate their product quality.

[4] Smyth and Phillips attempt to distinguish between the terms identity preserving production and marketing (IPPM) systems, segregation, and traceability. The authors define IPPMs based on the use of a grade-based premium to provide private market incentives. This is a rather limited definition in that such systems have little value apart from a segregation mechanism that preserves the purity of the product at successive stages.

butes. Such credence attributes may either be physical attributes (e.g., GM-free, Bst-free) or process attributes (e.g., free-range, "fair trade," country of origin). IPPMs require monitoring at successive stages of production to assure product quality and are typically characterized by a system of premiums or discounts to provide incentives for producers to supply specific product traits (Smyth and Phillips).

In addition to product monitoring and quality-based incentive systems, IPPMs are also typically characterized by some form of segregation system. As Smyth and Phillips explain, segregation is a quality-control process that maintains the integrity (or identity) of the product by preventing contamination or comingling of products. Segregation systems may require dedicated assets (such as dedicated bins at storage and assembly facilities or separate processing lines) or increased managerial effort to ensure facilities and equipment are cleaned of contaminating materials between processing runs. These may be in addition to requisite process controls required to create the credence attribute.

Information in IPPMs flows forward down the value chain, conveying the identity or attributes of the differentiated products. The system of premiums and discounts communicates information back up the value chain to producers, though not perfectly. Premiums may communicate the *average* value of the specific value trait but provide little in the way of producer-specific incentives for improved quality beyond the minimum grade standard for the IPPM system.

The Transaction Cost Reducing Role of Traceability Systems

Traceability systems have one general purpose: to reduce the transaction costs of coordinating the supply chain to produce a desired product. Inventory control and supply-chain management systems are perhaps most evident. EDI, RFID, and similar technologies reduce transaction costs associated with placing and processing orders, managing inventory, and settling of payment. By improving the ability to track and monitor inventory, costs associated with shrinkage and pilferage may be reduced. Electronic payment systems reduce uncertainty in accounts payable and receivable.

Systems designed to preserve or track quality reduce information asymmetry problems of adverse selection and moral hazard in the food system. Where there are premiums (or discounts) associated with difficult-to-observe quality attributes, producers have an incentive to misrepresent the quality of their products. Similarly, producers also have an incentive to shirk on costly quality attributes that may be difficult to detect. When agricultural products are blended across several producers, the incentive to shirk may increase as any one producer may perceive an opportunity to free ride on his peers' investments in quality; put another way, when products are blended the probability of detecting lower quality and assigning responsibility to the offending producer may be lower, thus increasing the incentive to shirk.

Facing such incentives on the part of producers, consumers at every stage of production demand credible verifications of the quality of the agricultural products they consume. This is particularly true in the case of food safety issues. The potential liability to food retailers of an incidence of food contamination is significant, not just in court-imposed sanctions but in loss of business as well. Incidences of *E. coli* contamination in fast-food retail are a case in point. Establishing traceability systems in their supply chains not only allows food retailers or processors to shift or share liability for food quality problems, but may also be a viewed as a minimum standard of reasonable care in assuring food safety.

A Framework for Considering the Effects of Traceability on Organization

The literature on traceability in the agrifood sector is relatively new, reflecting growing concern about food safety globally (particularly as regards GM products and BSE-tainted beef) and growing demand for credence-type attributes in food products. This literature tends to focus on the information asymmetry-reducing role of traceability (Hobbs, Burh, and Golan et al.), trade implications of labeling requirements, such as GM labeling (Loureiro, Carter and Gruere), country-of-origin labeling (Anderson and Hudson), or traceability in general (Claus, and Liddell and Bailey). While such studies highlight significant implications of traceability systems, there is not much attention given to the implications of traceability for the organization of agriculture.

An exception is Buhr, who studies the effects of traceability and information technology (IT) on the industry organization of meat supply. Buhr focuses primarily on the effects of IT, the boundary of the firm (vertical integration), and the organization of the firm. Drawing on transaction cost-based arguments such as those of Williamson, Hart, and Mahoney, he argues that none provides much instruction concerning the introduction of IT and the boundary or organization of the firm. To the extent IT affects variables associated with transaction-cost theories, such as monitoring and measuring costs, Buhr attempts to illustrate by case examples how IT affects the structure of six European organizations that employ traceability systems for meat products. What is missing is a more complete framework for analyzing transactions and organizational design at a given level of the value chain and how the nature of information capture and exchange affect the economics of the deal and thereby the governance of the transaction. This section addresses two necessary components of such a framework: the fundamentals of economic exchange and the fundamentals of economic organization.

The Fundamentals of Economic Exchange

Every economic exchange is comprised of three essential components: the allocation of value or the gains from trade; the allocation of uncertainty and, thereby, exposure to risk; and the allocation of property rights, including decision rights (whether explicit or implicit) that affect transaction performance. These three dimensions are integrally intertwined; changes in any one may affect the incentives and actions of contracting parties. Characteristics of the transaction, such as the nature of the product, the inter-temporal nature of the transaction, or the complexity of production processes, may influence the relative importance of any one or more of these exchange fundamentals.

For example, spot transactions of commodity products may involve very little uncertainty and little or no transfer of decision rights between contracting parties, other than property rights to the product itself. The allocation of value is determined by the prevailing market price for the commodity at the time of the sale. This is a relatively simple economic exchange, and consequently we typically see such transactions governed by autonomous, possibly even anonymous, spot market transactions. Add an inter-temporal dimension and the situation changes. Introducing time increases the potential uncertainty in the transaction since performance is now delayed and the future is by definition uncertain. How price is established at the time of contracting affects who will bear what type of uncertainty with respect to value. Since either party may be able to make decisions that influence the outcome of the uncertainty, including performance on the contract, we would expect parties to exercise those decision rights in ways that maximize their own net benefits in the face of the underlying uncertainties.

Similarly, a fundamental premise in option theory is the concept that the right to make a decision has inherent value, regardless of what the optimal decision may turn out to be. If a contract attempts to reduce uncertainty by reducing the decision rights of one or both parties, the constrained party foregoes a valuable decision right. In agriculture, we see such decision-right transfers in buyer's-call contracts, wherein the buyer dictates delivery schedules, and in production contracts that stipulate the inputs and methods of production to be employed. Although such restrictions may add value to the overall transaction by allowing more efficient product flow through the buyers' facilities in the case of call contracts or by ensuring a higher or more consistent quality output in the case of production contracts, how that additional value is allocated between buyer and producer may or may not take into account the reduction in value on the producer's side from a more restrictive set of decision rights.

It is important in this context to consider the source or nature of the value, uncertainty, and decision rights to be allocated in the exchange. For instance, in the case of GM-free IPPM systems, producers of GM-free products must make efforts to avoid contamination of their product by GM products, in addition to whatever other types of contaminants may be of concern (e.g., segregating GM-free from GM soybeans). What is the nature of the value in such a transaction? At the point of the farmer, the source of value comes from the segregation activity itself, not from the growing of the crop. The inherent trait is found in the seed genetics, thus any premium associated with the characteristic itself is likely to be included in the price of the seed. Preserving the integrity of that trait by keeping the crop free of GM contamination is the contribution of the farmer. Thus, in a competitive market, one would expect the premium paid farmers to reflect the marginal cost of preserving the integrity of the GM-free trait, all else equal. Of course, the production contract may contain other terms that affect value to the producer such as those discussed in the following paragraphs.

Uncertainty comes in many forms and from many sources. Agricultural producers are accustomed to dealing with yield and price uncertainty. Uncertainty in quality attributes is a relatively new concern, as difficult-to-observe quality traits become increasingly important sources of value. Uncertainty also exists in the behavior of contracting parties. These different sources of uncertainty suggest different types of risk exposure, as well as different types of measuring and monitoring mechanisms. The ability to accurately measure product quality, for instance, determines the types of controls and the nature of the premiums that can be established for quality performance. Likewise, the ability to measure contracting parties' level of effort from the volume or quality of output similarly affects the effectiveness of performance-based reward mechanisms.

Every transaction involves a host of decisions that potentially affect performance in the exchange relationship. The choice of inputs, production methods, investment in human and physical assets, exertion of effort or know-how, delivery, and payment are just a summary of the many types of decisions that are required for even relatively simple exchanges. To the extent contract parties have misaligned incentives and asymmetric information prohibits perfect enforcement of contract terms, exchange transactions are fundamentally characterized by the basic principal-agent problem (Jensen and Meckling). Positive contract theory (for example, see Hart and Hölmstrom) attempts to define efficient contracts in the presence of such misaligned incentives, implicitly linking the allocation of decision rights to contract terms that allocate value and exposure to uncertainty. In addition, contractual incompleteness may result in sets of decisions or contingencies over which contractual decision rights are not clearly defined. Grossman and Hart and Hart and Moore argue these residual rights of control (the noncontracted set of decision rights) are the basis for determining the efficient ownership of assets; that is, they are the basis for determining the degree or extent of vertical integration.

The Fundamentals of Economic Organization

Just as exchange transactions have three fundamental interdependent components, Brickley, Smith, and Zimmerman (hereafter referred to as BSZ) argue economic organization can also be broken down into three distinct yet interdependent dimensions: a structure of decision rights, a system of incentives, and a system of performance measures. The authors liken these three dimensions of "organizational architecture" to a three-legged stool; if any one dimension is inappropriately designed, the structure will be off-balance and perform poorly. Although their discussion tends to focus on business organization, the principles apply to the organization of any economic exchange, whether by (integrated) hierarchy or contract.

According to BSZ, decision rights should be co-located with information required for effective decision making. There are two competing constraints on the optimal location of decision rights: the cost of information flow to the decision point and the ability to construct incentives and performance measures to effectively encourage appropriate decision making. In this context, the role of IT in organizational structure becomes more apparent and one can develop more specific hypotheses about the effects of IT innovations. IT systems that enable more efficient (whether lower cost or higher quality) information flows may allow an efficient reallocation of decision rights in the exchange structure.

The link between incentive systems and performance measures is perhaps more obvious; effective incentive systems rely on effective performance measures. Effective performance measures capture the effects of decision making (behavior) on value creation within the transaction and are not subject to manipulation by the decision maker. Incentives can then be tied to performance measures that reflect the level of effort or decision making and its contribution to value, thereby creating stronger incentives for the decision maker. Here again, IT systems, for instance, that allow for the development of more precise (or more observable) performance measures, or that more effectively capture the value implications of decision making, may enable a reallocation of decision rights while maintaining an effective incentive system. In the context of traceability systems, changes in the ability to effectively measure quality attributes of output may change the optimal decision structure of the traceability system. In fact, improved measurement technologies can facilitate the identification of new product qualities that may have commercial value, thus leading to whole new traceability systems as traditional bulk commodities become more and more heterogeneous.

Mahoney's construct for organizational choice provides a useful framework for considering this triumvirate of decision rights, incentives, and performance measures. He described two types of measurement: task programmability and nonseparability of outcomes. Task programmability refers to the ability to control output quality by specifying input tasks that are easily observed or measured; that is, there is a high correlation between specific tasks in the production process and the resulting quality attribute of interest. Nonseparability refers to the ability to measure the value contribution of a particular input (whether tangible or intangible) by observing the output. For instance, it may be easier to measure a producer's level of effort in irrigated versus nonirrigated crop production, since irrigation reduces the effects of inputs (weather) beyond the producer's control. A similar argument is made in the context of production contracting in the hog industry, where climate controlled housing and improved genetics have reduced other sources of variability in hog quality. At the same time, standardization of production practices also increase task programmability. This is particularly evident in poultry production, and also to an extent in hog production. This is reflected in the nature of production contracts that specify inputs and management practices in an attempt to control the quality of production.

Note that BSZ's framework for conceptualizing organizational structure fits well with the fundamentals of economic exchange discussed above and provides guidance for the optimal allocation of value, uncertainty and decision rights. The incentive system not only establishes the division of value in the exchange but also contributes to the allocation of uncertainty, both with respect to the payoffs themselves and to the behavioral incentives guiding decision making. The nature of performance measures and their ability to effectively capture information concerning decision making and value creation also affect the allocation of uncertainty. Finally, the allocation of decision rights in the transaction must take into account both the location of relevant information and the ability to measure and reward the desired behavior. The location of the decision rights, given the performance and incentive systems, then affects the realized value of the exchange relationship.

Implications of Traceability for Agricultural Organization

The above framework highlights several critical questions concerning the implications of traceability systems for the organization of agricultural activities. These go beyond the simple cost-of-compliance-versus-benefits questions that dominate most of the existing literature and represent a large field for future research.

Beginning with decision rights, what are the critical decisions or control points in the value chain for the attribute under consideration? What is the relevant set of information required to make efficient decisions at that decision node? Finally, which party is best positioned, given the availability and cost of transmitting information, to most effectively exercise decision or control rights at that point in the process? The answers to these questions will depend on the availability and effectiveness of different monitoring and enforcement mechanisms, as well as the feasability of effective incentive systems.

In order to allocate value in the transaction in a manner that creates effective incentives, one first must understand the nature of value created by the traceability system. How is value created? Is it by creating and preserving specific product characteristics that command a premium from consumers, or is it the reduction in expected costs associated with the probability of product liability in the case of food safety? In the latter case, how is potential liability allocated among parties in the value chain and how does that relate to potential sources of quality or safety failure? Is it simply a reduction in the cost of transacting at one bilateral interface in the value chain where the benefits are completely captured at that stage of production? Note this question of value leads directly to an understanding of the critical decision points.

In addition to understanding the source of value, one must also understand the source of uncertainty in the incentive system itself. What factors affect value and performance? Is the incentive system susceptible to uncertainty, or noise, beyond the control of the decision maker? Can the incentive system be manipulated by either party in a manner that introduces uncertainty in the payoffs? How do these uncertainties in the incentive system affect decision makers' incentives?

In order to reduce uncertainty in decision making itself, one needs performance measures that enable efficient incentive systems and lower the cost of monitoring decision making. Is the nature of production such that incentives can be efficiently based on measurable output traits (i.e., low nonseparability)? Is production task programmable in a manner that would enable the contractor to exercise greater decision control? What types of performance measures do these characteristics suggest? Mahoney argues that when production is characterized by low task programmability and high nonseparability, the number of contractible performance measures may be insufficient to sustain efficient market-based contracting and may require more hierarchical coordination (i.e., all the relevant decision rights are transferred to the contractor via integration).

This list of questions is not exhaustive, but it illustrates the complexity of organizational dimensions involved in establishing traceability systems. Because traceability systems are based on information rather than simple quantity, or even purely quality, attributes, and because information is inherently asymmetric (hence the need for traceability), the challenge of aligning parties' incentives to invest in and produce the desired system characteristics involves an organizational response. Vertical integration may be one response (as in Buhr), but the real degrees of organizational freedom arise in the multitude of potential contract structures that may be adopted to coordinate production and information flows. This diversity in potential contract form is also an area of research that is greatly under-explored.

Lessons from the Real World

Although traceability is a relatively new issue in agribusiness, studies related to different types of traceability and information systems provide useful illustrations of the organizational implications of implementing such systems.

Traceability and Contracting in Video Rentals

Varian describes how changes in IT that allowed for tracking of movie video rentals changed the nature of contracting and vertical relations in the video distribution industry. Given the nature of retail rentals as a location-dependent activity, movie production companies sold videos (i.e., a fixed-price contract) to local rental outlets rather than franchising or otherwise contracting with outlets based on the level of rental sales. Sales or unit-based contracts would require the local outlet to self-report sales, creating a significant moral-hazard potential.

Video rental is characterized by relatively high fixed costs (physically producing the video cassette or, now, DVD) and relatively low marginal costs (providing the rental service itself). Perhaps the largest component of marginal cost is the opportunity cost of foregone rentals when a particular movie is out of stock. Given the large up-front cost of purchasing inventory relative to the cash flows generated by rentals, the short-term nature of demand for new releases, and the relatively longer life of the video itself, video stores carried limited stocks of movies, resulting in frequent shortages of popular movies. Moreover, the outlet also had incentive to continue renting a unit until its quality degraded from excessive use in order to maximize its return on its initial investment in the tape.

With the introduction of point-of-sale (POS) electronic data exchanges, movie distributors are now able to track specific inventory units as they are rented out, thus effectively monitoring rental sales activity. As a result, distributors began offering sales-based contracts to outlets, wherein the distributor effectively finances the inventory of the outlet by providing media on a consignment basis in return for royalties on rentals. Rental outlets carry a larger and more diverse selection of videos, increasing overall sales. Rather than continuing to rent out movies until the salvage value is zero, used videos are sold after a number of rentals and the revenues shared between the rental outlet and distributor. The sale of previously viewed movies offsets the costs of having larger stocks of popular new releases and disposes of excess rental supply once demand falls, enabling outlets to offer guarantees on new release availability. The entire system creates greater value than was possible under the incentives without traceability at the retail level.

Another consequence that Varian does not address is the resulting change in industry structure. POS systems not only reduce the costs of monitoring the relation between distributor and outlet, but also the cost of monitoring employees across multiple outlets. In addition, POS systems require a larger capital investment on the part of the retail outlet. Although anecdotal, the above arguments would also appear consistent with the rise of national movie rental giants, like Blockbuster, via acquisition of smaller, regional rental companies, and the decline of single-store local rental outlets that has occurred over this same period of the industry's history. This would suggest more than a mere contractual response to the introduction of traceability in video rentals.

Traceability and Integration in the Trucking Industry

Baker and Hubbard examine the effect of the introduction of on-board computers (OBCs) on the likelihood of vertical integration in trucking (2003) and the distribution of asset ownership in trucking (2004). In the vertical integration study, Baker and Hubbard argue OBCs have two potential effects, depending on the specific type of equipment installed. One type of system allows trucking companies to create stronger incentives for their drivers. The other allows for greater coordination of truck assets. They find that shippers are more likely to vertically integrate trucking when OBC equipment allows for stronger driver incentives. Conversely, OBCs that improved trucking resource allocation were associated with a greater use of for-hire trucking (i.e., contracting with trucking companies to provide transportation).

In their later study, the authors examined the effects of OBCs on the ownership of trucks by drivers and found that driver-ownership decreased with OBC adoption. They argue that OBCs improve the contracting environment between trucking companies and drivers, resulting in larger fleets of company-owned trucks. This effect was greatest for longer-haul trucking, where coordination of trucking assets is more costly due to thinness in the market at any particular location and where the monitoring benefits of OBC technology have the highest marginal value.

Inventory Traceability and Management in Food Retail

The use of EDI and similar systems to manage inventory controls has resulted in significant changes in contractual relations between food processors and retail groceries. As discussed above, Cachon (1995) demonstrates substantial logistic efficiencies associated with continuous product replenishment systems, wherein processors deliver smaller batches of inventory in an on-demand basis, controlled by inventory tracking systems and electronic transfer payment mechanisms.

In a more recent study, Cachon (2004) examines the effects of different contractual relationships between producers and retailers given the use of EDI on the allocation of risk within the supply chain and on supply-chain efficiency. In particular, he considers three different types of contractual relations: single-price-push contracts (where retailers preorder and hold their entire inventory stock at a fixed price), single-price-pull contracts (where the supplier holds the inventory and delivers as needed), and advance-purchase discounts, which apply a two-part pricing scheme allowing retailers to purchase at lower cost for advance orders (then holding the inventory) and requiring a higher price for additional quantities (with the production risk for additional demand borne by the supplier). Cachon develops a simulation model of the supply relationship and finds "the allocation of inventory risk matters for supply-chain efficiency even if firms are risk neutral" (p. 237). That is, the choice of contractual mechanism to coordinate the supply relationship not only reallocated risk between parties, but affected overall chain profitability.

Traceability in Production Agriculture

There is little systematic research concerning traceability and organization of the supply chain at the level of production agriculture. Golan et al. discuss economic theories related to traceability and provide an overview of the supply channels for produce and vegetables, grains and oilseeds, and meat products. They discuss some of the mechanisms used to facilitate traceability in each of these sectors as well as some of the challenges involved, given the nature of agricultural production, but they offer no economic theory either to explain or analyze the structure of traceability systems. Claus identifies shortcomings in the U.S. grain and oilseed industries' use of quality-control systems, such as ISO 9000:2000, arguing the United States has fallen behind other countries in providing such quality-enhancement processes. Martinez and Zering examine pork quality and the role of market organization. This is perhaps the most substantial analysis of industry organization as relates to ensuring a quality trait through the supply chain, but they do not specifically address issues of traceability.

Challenges for Traceability in Agriculture

As argued above, traceability requires an organizational response that addresses the allocations of value, uncertainty, and decision rights throughout the supply chain to assure accurate information flows and quality integrity. Designing an effective system requires more than simply gathering and transmitting data. Appropriate measures and incentives must be paired with decision rights and controls to effectuate a traceability system. The nature of agricultural production, the state of technology, and the information transmission of different traceability systems each suggest challenges for traceability in agriculture.

One challenge is the nature of information flows in traceability systems, particularly in segregation or IPPM systems. Information flows downstream toward consumers, conveying information about upstream activities, whether the use of inputs, production methods, or the integrity of a desired product characteristic. While this information flow allows the entire supply chain to capture value from consumers, little information flows back to individual producers in a manner that creates incentives for improved quality due to the bulk-commodity handling of many IP products past the farm gate. Premiums paid to individual producers are based on the average quality of the pooled products marketed downstream. Thus, even with a performance measurement system that guarantees a minimum level of quality and a segregation system to preserve the trait, there remains an incentive to free-ride on others' high quality to attain the pool average.

This leads to a related challenge, the ability to actually measure the desired quality characteristics at each stage of production and the incongruence between contract terms (explicit incentives) and performance measures. For instance, tests for genetically modified soybeans employed by most U.S. elevators are simple strip tests that detect the presence of any GM content on a simple yes/no basis. However, contracts for GM-free soybeans stipulate different percentage thresholds for allowable GM content (Sykuta and Parcell). As a result, a producer with a contract stating a 3% contamination threshold as the basis for a segregation premium may have deliveries rejected at far lower levels of contamination based on the actual performance measuring technology. Barnes models costs of alternate GM-threshold allowances and finds contractual thresholds are not binding constraints because the contracts are effectively enforced based on zero tolerance. Such mismatches between performance terms and actual performance measures create weaker incentives for producers and may also raise questions about the legitimacy of the contract terms.

An alternative to contracting on difficult-to-measure output characteristics is to specify inputs to the production process. Changes in production practices and genetics have increased the task programmability of some agricultural production. However, contractual forms that stipulate inputs and managerial practices risk being interpreted as employment contracts rather than independent production contracts. Hipp and Francis discuss the potential legal and liability implications of such a reinterpretation of contract forms. An unresolved question is the likely organizational response to such rulings. If managerial control is needed to ensure quality outputs, one may expect a move toward even more vertical integration in production. If alternate measures of performance can be implemented contractually with minimal loss of productivity, one may simply expect a change in contracting practices that reduce task specifications and rely on other measures of performance.

The final challenge I will address here is the ability to accurately define and measure the value implications for transactions in traceability systems. How is the value associated with the product or process employed at a given level of production in the value chain to be measured and allocated among contract parties? How are the costs of traceability accounted for in the transaction, whether record keeping, changes to and investments in facilities and other assets, adaptations to production practices, or other cost factors? The risk and potential cost of liability for product quality is another significant value issue, particularly if liability-invoking failures may not be completely subject to managerial control. Even if the probability of liability is extremely low, the amount of liability may create an expected value of significant economic consequence, particularly for smaller agricultural producers. Contractual relations may play a significant role in the allocation of liability across members of the supply chain.

Conclusions

There are several economic drivers for creating privately ordered traceability systems. In order to understand the potential effects of traceability systems on the organization of the agrifood industry, one must first understand the fundamental elements of economic exchange and the fundamental elements of economic organization. Given that framework, one can begin to explore the economic and organizational consequences of developing systems to more tightly integrate and exploit the value of information about agricultural products. In this paper, I outline such a framework and attempt to illustrate both the importance of considering the organizational implications of traceability as well as some of the challenges for developing effective traceability systems in agriculture.

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