Traceability and Information Technology in the Meat Supply Chain: Implications for Firm Organization and Market Structure

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The traditional food supply chain is arranged as a complex array of producers, handlers, processors, manufacturers, distributors, and retailers. As the food supply chain grew in complexity over time, little emphasis was placed on preserving information regarding the origin of raw materials and their transformation, often by multiple handlers, into consumer-ready products. This paper provides case illustrations of the implementation of information systems for support of traceability in Europe. Observations on these firms coupled with the literature on information asymmetry and transactions costs is used to provide insights into how traceability implementation might affect U.S. meat-industry structure.

Food safety issues in meat and livestock have come to the forefront in recent years. High profile incidences of contamination by *E. coli*, BSE, dioxin, hormones, and antibiotics have contributed to a desire to find ways to improve quality-control systems in the meat supply chain. The meat industry has also implemented extensive branding of non-observable product attributes (credence attributes) including hormone-free (e.g., Coleman Beef) organic, free-range, and antibiotic-free , in an attempt to differentiate products to consumers.

In response to demand for improved quality control and differentiation, the U.S. meat sector has undergone market structure changes (Lawrence et al. 1997; Hurt 1994). Martinez (2002) succinctly describes the structural change of the U.S. meat and poultry sector towards vertical coordination and contracting in the 1990s as driven by concerns for "improved quality control demands of specialized large scale production systems." He further states that contracts and vertical coordination "provided an efficient means of organizing markets by reducing these transactions costs."

Into this combination of increased demands for food safety in meats, differentiated product attributes, branding, and structural change has come the information technology revolution exemplified by the Internet and the underlying information-technology hardware (e.g., increased computer processor speeds, increased data-storage capacity, electronic data capture and measurement devices). Information technology (IT) and information systems (IS) have made it economically feasible to develop logistics management and monitoring which enable traceability of food products through the labyrinth of the agricultural food supply chain. Because traceability and information systems reside at the nexus of firms' market interface it is naturally expected to have implications for the already evolving meat supply-chain organization.

A few recent economic studies have addressed the traceability issue. Liddell and Bailey (2000) examine the broader market implications of traceability by ranking the relative development of traceability systems in the U.S. to other competing countries in world markets. They suggest that the U.S. lags in areas of both food safety and quality control, particularly when compared to European suppliers such as Denmark and the UK. A recent study by Dickinson and Bailey (2002) shows that consumers in the U.S. may be willing to pay for traceability and transparency in meat products. Hooker, Nayga, and Siebert (1999) examine the food-safety activities in the beef industry and primarily focus on the results of surveys regarding the ability to implement food-safety practices, including traceable supply chains. Most processors in the U.S. and Australia viewed this as technically feasible, but the particulars of how it might be implemented or the economic costs of implementation are not directly addressed. Hobbs (1996) develops an economic-engineering approach to examine implementation of traceability in beef processing.

This paper seeks to address the broader market structure and governance issues related to traceability through examination of existing meat supply-chain traceability systems in European meat

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and poultry processing firms. The paper integrates the theory of firm organization and integration with case-study observations from Europe. First, the fundamental market-structure issue of *why* traceability is adopted in meat supply chains is addressed. This is followed by focusing on *how* traceability is expected to affect meat supply-chain organization and structure couched in the literature of the theory of the firm. Finally, the direct internal firm economic implications are examined; these include the implications for recall costs and the impacts of traceability-derived process-information effects on production management.

Case Methods and Participants

Six European organizations employing traceability programs in meat or poultry were chosen for this investigation. The criteria for choosing participants was that they must have an electronic-based traceability system which encompasses live-animal production through retail sale of meat or poultry products.

Primary contacts were made through USDA Foreign Agriculture Service offices in the country of the firms; contacts were then followed to identify key personnel in the production system. The six participating entities include a poultry-production system (Label Rouge/Challans, France); an egg-production system (KAT/Wiesengold, Germany); a salmon-production system (Intentia/Nutreco, Norway); a veal-production system (The VanDrie Group, Netherlands); a lamb, pork, and beef supply chain (Scase-Intentia/Gilde, Norway); and a beef-production system (Scotbeef, Scotland). In examining these systems several supporting organizations were also visited, including the Poultry, Livestock, and Meat Board in the Netherlands, several governmental agencies in France, Carrefour supermarkets in France and ASDA supermarkets in the UK.

Table 1 provides a summary of the characteristics of the firms included in the case studies. The objectives of the site visits were to document the supply-chain production protocols, to examine alternative forms of governance structures for supply-chain traceability, and to document methods of electronic traceability. A team of two researchers conducted site visits. Site visits included one- or two-day visits to key production facilities (feed mill, farm, processing, and retail). The team also met with key personnel at each stage of the process to interview them regarding their experience.

In all cases, the traceability systems extend from the feed-manufacturing process through retail. Also, each case has unique production protocols that support the development of particular consumer-product attributes such as organic, group-housing, free-range, or antibiotic-free production. All are also clearly focused on the issue of food safety. The production protocols typically stipulate production inputs such as feeds, health treatments, animal-rearing methods (e.g., non-cage, group housing, free-range) and genetics. Production protocols are enforced at all stages of the production process by third-party auditing of production records. Methods for monitoring production included sampling of feces, feed, or meat; cross-referencing feed-delivery timing and use to correlated production variables such as daily gain; and site visits by auditing firms or certified veterinary or farm-management services. Finally, all firms had vertical organizational and governance structures to manage and implement the production and information systems.[1]

Why is Electronic Supply Chain Traceability Adopted?

When case participants were asked why they adopted traceability, the first response in every case was, "Consumers demanded to know where their food came from and how it was produced." Historical food-safety issues such as dioxin contamination; BSE in cattle; radiation contamination; and increased demand for organic, non-GMO, or free-range products were all cited as contributing to the consumers' preferences. Mostly these are credence attributes that are only verifiable by assurances of the seller.

To achieve the objective of informing consumers of quality, all case participants had implemented branding and product labeling. For example, Label Rouge is a labeling scheme created by the French Ministry of Agriculture that can be used only if food products meet a specified production protocol, certification/auditing process, and observable quality difference from other food in the category. The consumer relies on the assurances provided by the

[1] The specific production protocols, tracking systems, auditing procedures and their organizational structures are too detailed to report here. They are available from the author upon request.

Table 1. Overview of Firms in Case Study.

	Challan/ Label Rouge	VanDrie Group	Gilde Norge	Scotbeef	Wiesengold/ KAT	Intentia/ Nutreco
Product	Chicken	Veal	Pork, Lamb, Beef	Beef	Eggs	Salmon
Country	France	Holland	Norway	Scotland	Germany	Norway
Attributes	Free-range, organic, genetics	Hormone-free, group housed	Hormone-free, humane rearing	Hormone-free, humane rearing	Free-range, organic	No specific criteria
Organ-ization structure	Govt. authorized 'syndicate'	Vertically integrated, feed/calf raising/ packing	Co-op	Independent contracting	Cooperative KAT is standards organization	Vertically integrated
Quality assurance	Govt. audited, syndicate controlled standards	External audits, self-imposed standards	External audits, self-imposed standards	External audits, self-imposed standards	External audits, standard defined by KAT	External audits, self-imposed standards
Info. systems	PC-based records, labeling	Internet-based system	Internet-based system	PC-based system	Internet-based system	Internet-based system
Traceable activities	Feed, farm, slaughter, retail	Feed, farm, slaughter, retail	Farm, slaughter, retail	Feed, farm, slaughter, retail	Feed, farm, packing, retail	Feed, farm, processing, retail
Depth of trace	Individual bird	Individual retail cut	Individual retail cut	Individual animal	Individual egg	Individual pond
Method of tracing	Wing tags, manual reading	Barcode and ear tags	Barcode ear tags	Passports ear tags	Numerical code printed on eggs	Unknown

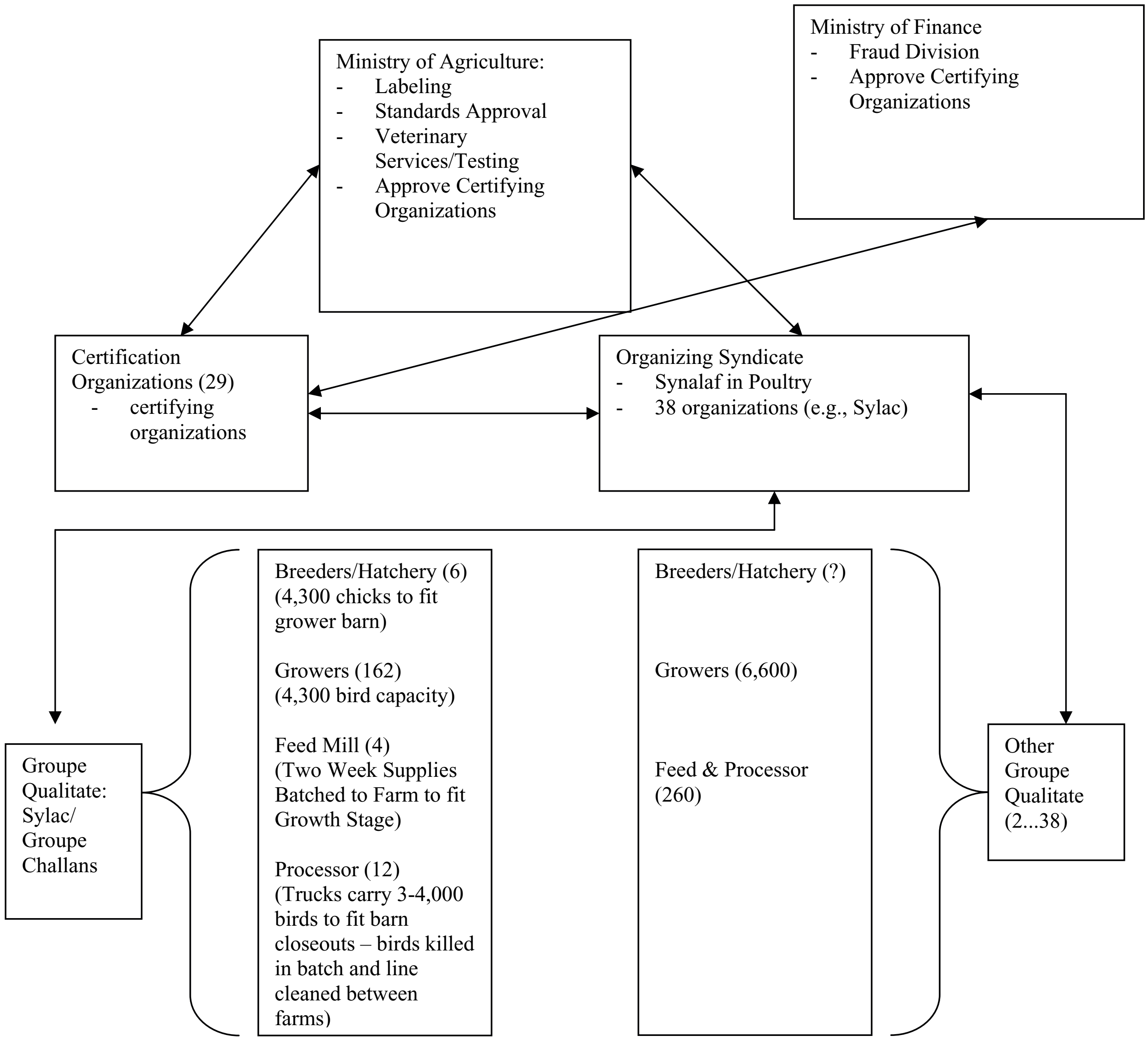
Label Rouge brand with government assurances. KAT/Wiesengold (eggs) and the VanDrie Group extended their branding claims to include their unique production standards and auditing systems along with numerical or bar codes on their products. The bar codes can be used by consumers to access websites and learn more about where their products originated (farm through packaging), a limited set of information on the production protocols, any quality-assurance tests which had been done, and their results. For an illustration, visit VanDrie's customer website at http://www.vealvision.com.

The immediate question is why didn't these organizations view traditional branding as sufficient for providing consumer assurances between the final handler and the consumer? [2] Akerlof's (1970) seminal article on the used-car market points out that information asymmetry between the seller and buyer can lead to market failure. For the traceability cases described above, the relevant argument presented by Akerlof is that "lemons" or poor-quality products drive out the "good"-quality products if the seller knows the quality of product while the buyer does not. Therefore, the argument that "consumers demanded traceability" rests on the fact that many of the product attributes claimed (organic, free range, group housed, specified feed or ingredient treatments) are unobservable to the final consumer and so may be regarded with skepticism. However, as described by Leland (1979), product labeling, licensing or certification, and repeat purchases are key remedies for information asymmetry between the seller and buyer. The consumer can identify the brand, and if inferior quality is discovered the consumer will either seek compensation or the reputation of the brander will be damaged so that repeat purchases will not occur. In this case, Label Rouge's branding and certification scheme (see Figure 1) would be viewed as sufficient without the need to adopt traceability per se as a further assurance mechanism to the consumer as all cases have done. This is borne out by VanDrie, KAT, Gilde, and Scotbeef, who report that they have not been able to capture any additional profits beyond their branding due to traceability systems per se. The premiums observed are in fact attributed to the product-attribute claims such as organic or free range that were labeled prior to the implementation of traceability.

The argument for branding and labeling as a remedy for information asymmetry only holds if the final handler has total control or certainty over attribute claims made in the production process. Production uncertainty is potentially exacerbated in the food supply chain with the interdependence of production processes undertaken by upstream firms independent from the final handler and with the additional potential for agency problems such as moral hazard or opportunism. Hennessy (1996) addresses the issue of information asymmetry in the context of product quality and grading uncertainty at the wheat farm---grain elevator interface. Hennessy demonstrates that, given quality uncertainty, the inability of grading systems to adequately identify food quality standards, and the presence of costly and destructive testing, a price-grade incentive structure will cause an "under-investment in farm-level food quality control." Hennessy also explicitly makes the caveat that this is especially the case when "food leaves the farm and is not primary-source identified thereafter." Under-investment issues become even more acute and cumulative when the quality trait of concern might enter at multiple stages of the supply chain as is the case in many food-safety examples such as *E. Coli* or salmonella contamination.

The key question now is phrased slightly differently: why isn't simple product labeling within the supply chain also effective in solving the information asymmetry problem? As suggested by Williamson (1981), the cost-benefit relationship of overcoming information asymmetry within the supply chain turns on the issues of agency costs (correcting for moral hazard and opportunism) and transactions costs to determine their effectiveness. Agency cost in this context is a subset of transaction costs involving monitoring of compliance by the principal (in the cases studied here, the principal would be the firm holding the brand or trademark; e.g., KAT, Label Rouge, VanDrie, Scotbeef) or final handler (Mahoney 1992; Jensen and Meckling 1976). Some attribute specifications or cost incurrence by the agents (farms) to achieve differentiation are easily observable to the principal. Examples

[2] The final-handler terminology is used because often the final meat product was branded as a case-ready product through retail. In this case, while the grocer might be the true interface with the consumer, the branding done by the case-ready manufacturer is the identity presented to the consumer and the one who will be identified with any substandard product attributes. In other cases, the grocer was both the brander and the final handler.



- Ministry of Agriculture and Ministry of Finance both approve Certifying Organizations.
- Certifying Organizations report to both Ministry of Agriculture and Ministry of Finance.
- Synalaf is a Quality Groupe that oversees all Label Rouge Poultry
- Sylac falls under Synalaf as one particular set of standards for Label Rouge Poultry. There are many other Groupes.
- Synalaf acts as liaison for standards approval and control for producers
- Sylac manages operations of groupe – maintains records, reports to Synalaf on controls, coordinates quality certification (e.g., site visits), and reconciles traceability checkpoints (e.g., feed quantity w/ number of birds fed or chicks delivered and chicks slaughtered.
- Ministry of Agriculture, Certifying Organizations and Sylac/Synalaf all maintain databases of relevant information, but these don't necessarily communicate.

Figure 1. Sample Organizational Structure of Label Rouge.

include free-range production or group housing. However, others—such as the purchase of organic feed inputs or the abstinence from antibiotics or hormones—are more difficult to assess and incur greater monitoring costs. Moral hazard and opportunism become even greater issues when products are aggregated, disaggregated and mixed, when there are long lags between consumption and the manifestation of the product defect (e.g., BSE), and when the product-attribute value becomes greater. For example, KAT reported wide-spread cheating by farmers misrepresenting conventional eggs for organic eggs prior to traceability because the price of organic eggs was approximately twice the price of conventional eggs.

A similar problem emerges in employee-team relations and (Jones 1994). As the final value of the differentiated product becomes higher and task or input visibility becomes lower, the incentives for shirking or free-riding become greater. Further, in the circumstance of low task observability and high differentiation value, there is a strong potential benefit to monitoring, but the costs become greater as monitoring typically requires an increased numbers of supervisors. The analogous "team" problem in traceability is that the final handler (packer or retailer) acts as a supervisor by bearing responsibility for quality and aggregates a large number of producers (employees). This explains why final handlers nearly always direct the production systems. "Packer-marketers" organized KAT, Ekro (the meat processor) coordinated the VanDrie Group, and Scotbeef was coordinated by the packer at the instruction of retailers that used store branding.

This finding has implications for how U.S. firms make the decision to adopt traceability. Consumer demand in itself is not a sufficient primary reason. Branding, labeling and certification can overcome the handler-consumer information-asymmetry problem. However, the attempt to overcome information asymmetry between the final handler and consumer through branding, combined with inter-firm supply-chain information asymmetry and production uncertainty concentrates the incentive for traceability on the final handler, who then has an incentive to require compliance by suppliers. Figure 2 provides a decision schematic for assessing whether firms should consider traditional remedies such as branding, labeling, and certification programs or if supply-chain traceability might provide a superior solution. Ultimately the decision will depend on careful consideration of the empirical implementation costs and expected value of reduction in information asymmetries.

Overcoming Supply-Chain Information Asymmetry: Organization and Traceability

Historically, the organizational literature suggests the remedy for information asymmetry in the production chain is for firms to vertically integrate or contract to reduce transaction and agency costs (e.g., Coase 1937; Williamson 1971, 1981, 1985; Hart 1995). As transactions costs, moral hazard, and information asymmetry increase, the "make or buy decision" increasingly tilts toward "make" and the firms vertically contract or take direct vertical ownership.

As summarized in Mahoney (1992), transactions-costs theory suggests specific advantages of vertical ownership, including profit allocation, coordination and control to overcome supply uncertainty, superior auditing powers of the firm compared to open market mechanisms, ability to motivate directly, and effective communication of information (see also Williamson 1971).

However, there are noted downsides to vertical ownership and contracting, including the fact that contracts are incomplete (Hart 1995; Williamson 1971). In particular, this can lead to a unique form of transactions costs described by Williamson (1981) as "asset specificity costs." If firms must invest in specific assets, they will be subject to opportunism or hold-up and are not likely to invest in systems, which are costly, in order to provide the desired output quality to downstream firms. Jones and Hill (1988) describe disadvantages as increasing the size of the organization, which increases the potential for exceeding bounds of rationality (see also Williamson 1981). Williamson (1985) further suggests that vertical ownership blunts high-powered market incentives that can undercut the primary profit motive. Mahoney (1992) summarizes the disadvantages to vertical financial ownership as limited access to knowledge of other suppliers, excess investment in sunk costs, high exit barriers, inability to achieve synergy in economies of scale at multiple stages of the supply chain, and related capacity imbalances. In summary, while vertical integration may serve as a governance solution to problems of information asymmetry, agency, and transactions costs, it remains an empirical decision to determine whether

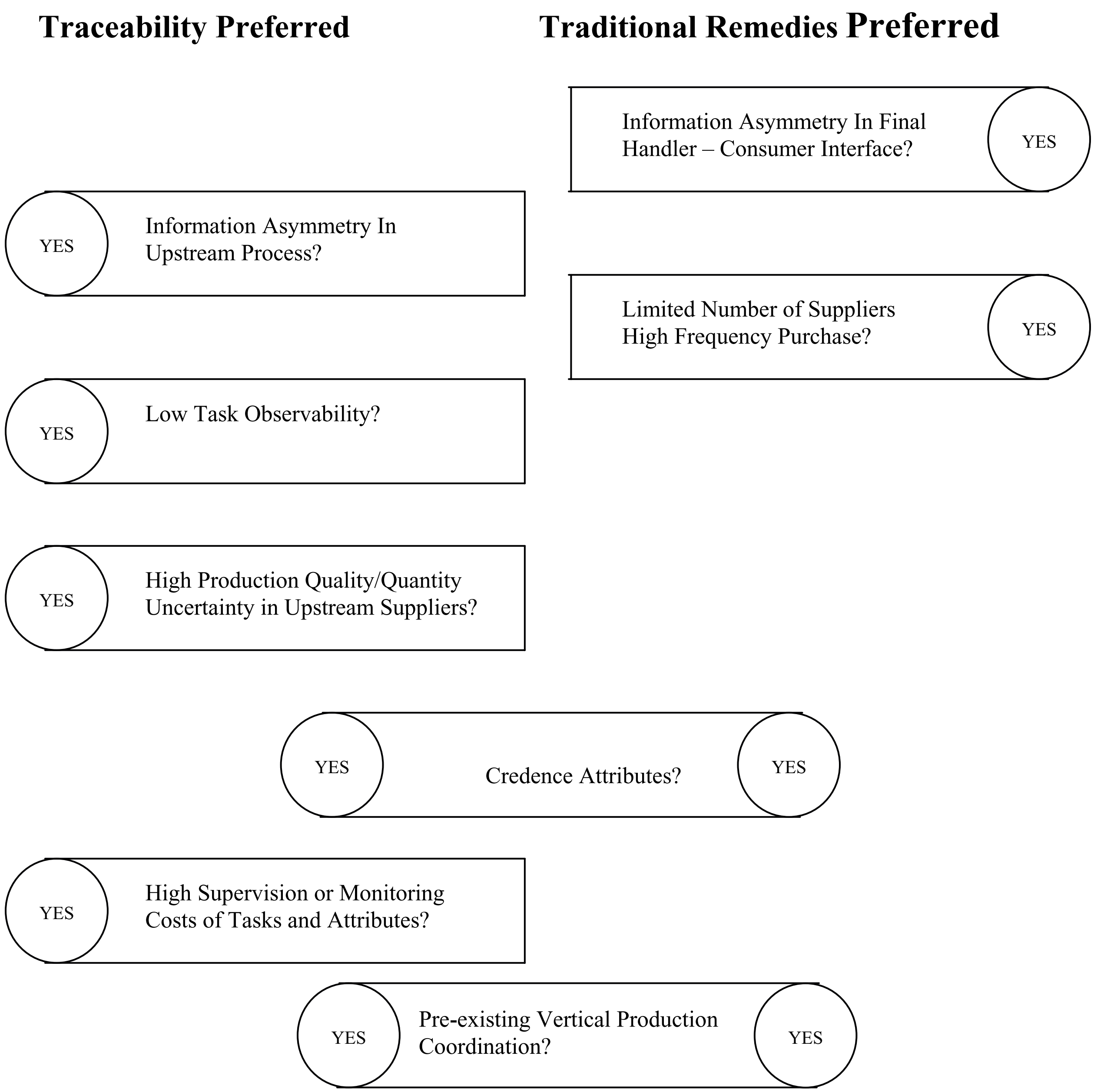


Figure 2. Balance of the Decision Process for Traceability or if Traditional Remedies Such as Branding, Repeat Purchases or Certification/Licensing Are Sufficient.

firms facing the primary issues of improving food safety while offering products with unobservable attributes should develop vertically aligned governance structures. This in turn depends on the costs of open-market acquisitions (search costs), supply uncertainty (both quantities and quality), and monitoring and certifying costs versus complete vertical control where the supply-chain integrity can be managed by fiat but which will incur the deficiencies described earlier. As stated by Williamson (1981), "The object is to match governance structures to the attributes of transactions in a discriminating way." None of the literature examined, however, addresses this issue when information technology is adopted at the boundary of the firm as it is in traceability.

Traceability: Description of Information Technical Change at the Boundary of the Firm

As suggested in the firm organization literature, monitoring costs of compliance necessary for certifying can be extremely high even in internal production processes (Jones 1994). Additionally, without information systems that can coordinate thousands of individual farms, animals, and resulting meat products, even a vertically integrated firm would likely experience the limits of management's ability to oversee the complex supply chain (bounded rationality, as in Williamson 1981).

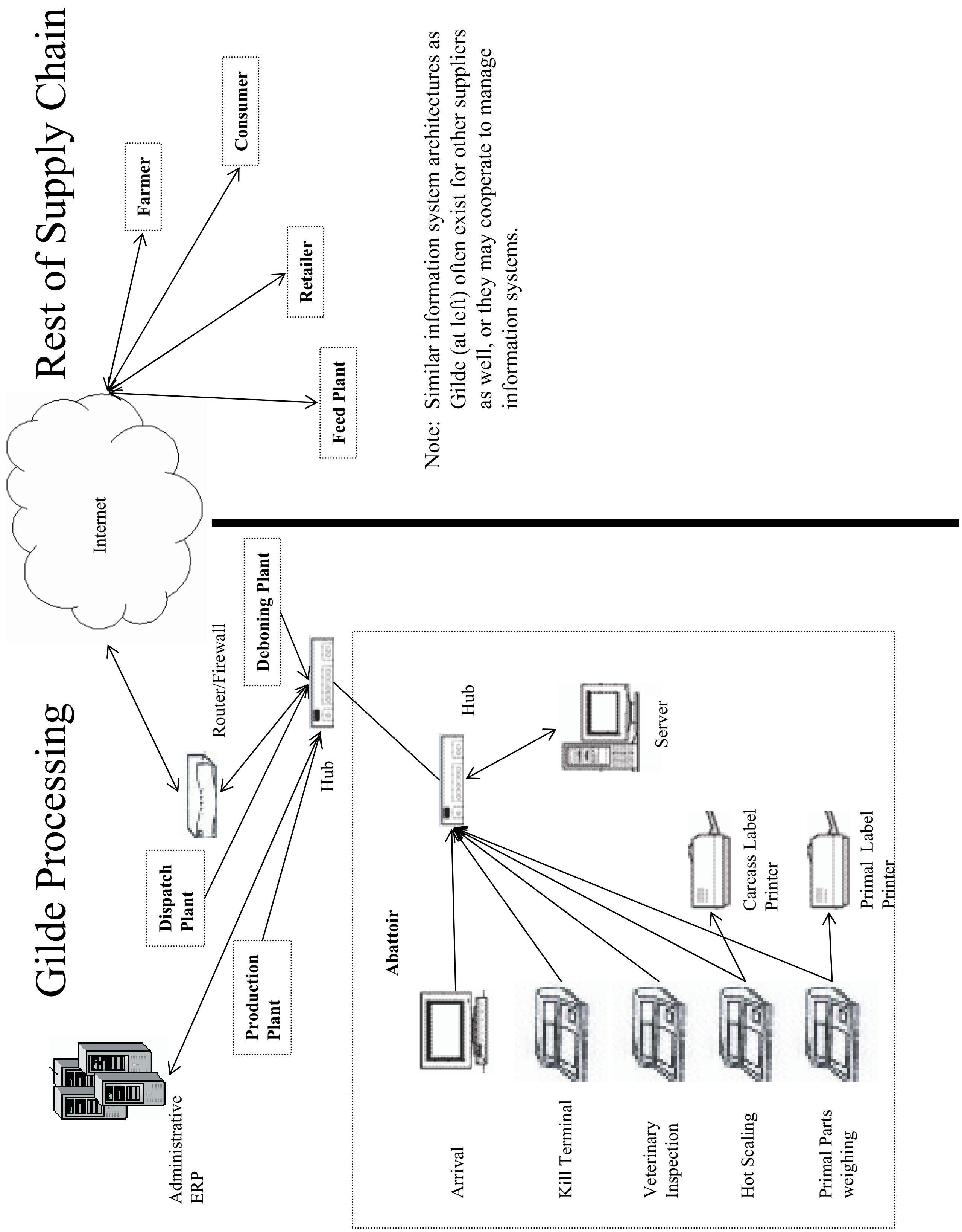
While information systems will be shown to assist management and coordination, logistics management in production is also critical. Animal supplies, slaughter times and locations, feed deliveries, and other aspects are all tightly coordinated. Animals must be identified when they are born, carefully tracked as they are moved between farms, and then tracked at slaughter if they are to be identified by the final product. The most intensive points of logistics are at aggregation/dispersion points for inputs (e.g., feed plants with ingredient inputs and packing plants where carcasses are disassembled). Batch integrity quickly becomes an important production-management tool by reducing the sheer number of observations (e.g., animals vs. pens vs. barns vs. farms).

For example, the VanDrie Group veal-processing system tracks individual animals through the processing chain to the point where a final retail-portion cut at retail could be tracked to an individual animal. This incremental product-tracking system required them to reconfigure their entire cut floor and handling system in manufacturing fresh veal cuts. They estimated costs for complete implementation of the information system (scanners, production-chain changes, additional employees) in a single veal-processing plant at $6.5 million and approximately $24 million dollars to implement it across their feed manufacturing, farms, and processing plants.

To put the costs in perspective, the VanDrie Group consists of two slaughter plants which each slaughter approximately 350,000 head of calves per year, 100 farm operations, three veal fabrication and processing plants (primals are shipped in and converted to case-ready) and two milk-powder manufacturing plants for feed (~100,000 tons per plant per year). To contrast, Gilde, which had recently built a slaughter plant capable of individual cut tracking, estimated the cost of the information system components (i.e., industrial personal computer stations, servers, and software) to be only about $150,000 for a single slaughter plant similar in capacity to VanDrie's Ekro plant. While these figures are rough estimates, it illustrates the point that the information-system requirements are relatively inexpensive, but configuring the production process to maintain traceability to the cut level is quite expensive. Thus a very important consideration is the economic trade-off inherent in the level of traceability desired (e.g., individual retail-ready cuts vs. individual animals, vs. farm, etc.).

Figure 3 shows a schematic of Gilde Norge's information system implemented with assistance from SCASE (hardware development) and Intentia (software development). It is representative of other state-of-the-art systems observed. Figure 3 shows an overall product-supply chain including farms, ingredient suppliers (for simplicity simply feed, but can include seasonings at processing), the retail/distribution stage, consumers, and the slaughter and processing plant itself. The vertical members of the supply chain all connect into the traceable information flow via the Internet; there is typically a dedicated server that provides the interface and database for the traceability data.

Each entity may maintain their own servers for their specific databases and simply allow queries through their firewall, or there may be a central system managed by one of the entities on behalf of the participants. The latter is often the case between farms and processors or feed suppliers, since few farmers have the information-technology access



Gilde Processing
Rest of Supply Chain
Internet
Farmer
Consumer
Retailer
Feed Plant
Note: Similar information system architectures as Gilde (at left) often exist for other suppliers as well, or they may cooperate to manage information systems.
Router/Firewall
Deboning Plant
Hub
Dispatch Plant
Production Plant
Administrative ERP
Abattoir
Hub
Server
Carcass Label Printer
Primal Label Printer
Arrival
Kill Terminal
Veterinary Inspection
Hot Scaling
Primal Parts weighing

Figure 3.

(knowledge or capital) to create an internal information system with Internet capabilities.

Underpinning the Internet—which allows connectivity between firms—is each firm's internal information system or enterprise resource planning systems (ERPs). ERPs are simply the platforms on which company-specific information resides (a prototypical structure is shown in Figure 3). The ERP will locally store all information regarding all activities electronically collected by the firm. The left side of the diagram illustrates the structure for Gilde to actually interface the physical data of the product with the digital traceability record.

A good example of the efficiency of these systems for managing products occurs in the case of feed milling. Navobi, one of the feed suppliers for the VanDrie Group, uses electronic ration balancing for their milk-replacer mixing. As a result they are able to uniquely identify all sources and quantities of ingredients in each batch of milk replacer. A subset of this information (ingredient list, batch identification number, and microbiological assays) is uploaded to their web server and can be accessed via a password. Subsequent stages in the chain (veal farmers and packers) can examine this information, but cannot access other information which may be proprietary, such as the proportion of ingredients used in the formulation or the price of ingredients. The merits of this information system are considerable, in that it captures the efficiency of production-management systems, enabling efficient transmission of information to upstream and downstream participants in the chain while maintaining security for the entity.

A component equally important for gathering data is measurement hardware. Weigh scales with data ports, visual carcass-grading technologies which enable capture of key carcass parameters, and water-monitoring devices for measuring mixing ratios of calf-milk replacer are all examples of data-collection devices which greatly enhance the ability to capture production information. These lower the transactions costs of collection by reducing labor requirements, improving accuracy, and avoiding the error (or moral hazard) of human input. At this point, processing plants (feed and meat/egg) have a much higher level of automated data collection hardware than do farms. This is particularly true in cases where the farms are mostly independent from the rest of the chain.

In addition to measurement devices, there must be methods to physically identify products. The everyday barcode is still the primary method for labeling products. In the VanDrie case, each animal enters the plant with an ear tag printed with a 12-digit barcode. This barcode is the animal's identification number and is cross-tabulated with the truck license plate and farm information, which has been manually keyed into a personal computer with a local area network connection. The animal-identification number remains with the carcass at all times through sequential bar-coding. At the processing stages where primals and subsequent cuts are removed, barcode tags are created by printers and attached to each part of the animal as it is removed from the aggregate carcass. The unique barcodes of each cut are also entered into the ERP system. This process continues until the final case-ready product is labeled with a barcode (this is in addition to the sale barcode, which contains pricing information as well) and can be identified through retail scanning. Two firms (Gilde and VanDrie) experimented with implantable microchips and radio frequency transmitters (RFIDs) but found them to be unreliable (migration in the animal and reading problems cited) compared to inexpensive barcodes.

Traceability: Implications for the Organizational Structure of the Firm

Information technology and traceability represents a technical innovation to reduce information-transactions costs. It does this by enabling improved reporting by providing access in real-time, which improves planning decisions in the supply chain, and by providing a digital record of transactions which is easily queried should there be a need to trace a product. It can also improve monitoring, since electronic certificates and passwords accessible only to key personnel (such as certifying agencies) can secure the databases. The interesting question is whether this transaction-cost-related technical change will lead to greater incentives for vertical ownership, facilitate improved contracting relationships, or even favor open markets if relevant information is readily available to all buyers and sellers. From a purely transactions-cost perspective it would appear that this would tilt the balance toward open markets because of improved communications (Williamson 1971) and improved monitoring (Leland 1979). In addition, the implementation of on-line measurement hardware which continuously monitors and measures direct production reduces the potential for agency problems (i.e., opportunism of recording misinformation is also reduced). Conversely, traceability with information networks overcomes the limitation of bounded rationality in favor of vertical integration and scale economies, and may improve the ability to approach complete contracts (Hart 1995; Williamson 1971) with improved information and monitoring.

The impact of information technology and information systems on organizational structure in the previous literature is ambiguous. Malone, Yates, and Benjamin (1987) predict that the greater use of networks would lead to more market-like relationships among firms. However, Steinfield, Kraut, and Plummer (1995), in a broader survey of previous empirical research regarding inter-organizational structure with electronic networks, conclude that the more extensively firms use inter-organizational networks the more hierarchical are their trading relationships, even in cases where they are using public networks (such as Teletel in France). Private networks, as described in this paper, are even more likely to be hierarchical and to have closed supply chains because of switching costs of participants leaving the network. Steinfield, Kraut, and Plummer also suggest that there is some evidence that it is easier to include lower-volume trading partners with fewer transactions due to lower per-unit transactions costs.

Based on the observation of European firms, traceability has been implemented successfully in vertically coordinated production systems (e.g., Label Rouge, KAT/Wiesengold, Gilde, Scotbeef) and vertically integrated production systems (e.g., VanDrie Group and Nutreco). In no case was there a move to more open market structures for procurement. In fact, VanDrie had difficulty coordinating their conventional beef operations for traceability because it requires more than 500 growers, versus the 100 growers who supply their veal operations. In sum, the evidence from the European case studies and the literature suggests that the benefits derived from integration and production coordination among a closed production network of suppliers outweighs potential benefits the electronic network might create related to finding new sources of supply in an open market. By extension, those organizations which are already vertically integrated or coordinated through production relationships will likely find that traceability and information technology directly improve their management efficiency. The one caveat is that if information networks operate on an open basis with common standards, firms may eventually learn organizational strategies that improve flexibility (a key disadvantage to integration described earlier) while moving some transactions to an open market (Malone, Yates, and Benjamin 1987). Figure 4 provides a schematic of the decision structure relating to choice of organizational structure with traceability and information networks.

Additional Economic Implications for the Firm

Although beyond the scope of this paper, there are additional observations which warrant further consideration in regard to adopting traceability and information systems. In all the cases we observed, the participants reported that some of the greatest economic benefits were from the production information and data generated as they began to monitor production processes more closely.

Learning by Using, Learning By Doing, and the Direct Firm Value of Traceability and IT

As described earlier, traceability was adopted primarily as a supply-chain-management program driven by consumer demand. However, participants reported that they quickly learned that traceability has internal production benefits from improved information and control of production. This learning by using (Sundig and Zilberman 2001) stems from the incorporation of ERP systems at the firm level that inherently improve data collection as well as from analysis, diagnosis, and response to potential production problems.

Gilde Norge, the Norwegian slaughtering plant, provides an example of the direct production-management benefits. In implementing traceability, they incorporated a visual grading system that ultimately allowed them to benchmark expected meat-cut yields from a carcass to its actual yields. The ongoing real-time analysis of carcass cutouts is attributed with adding five to seven percent to their final meat yields. This added internalized profitability might be the greatest direct benefit when the ambiguity in the context of the firm organization benefits is considered.

Food Safety and Recall Costs

Earlier it was suggested that overcoming information asymmetry at the final handler-consumer interface alone was not sufficient for traceability with branding. However, traceability at this interface has great benefits for reducing the recall costs of substandard products. This can also extend to recall situations within the supply chain interfaces.

Navobi, the calf-milk replacer manufacturer, provided an excellent example of this point. Their veterinary services identified a salmonella problem in routine on-farm testing. Through their traceability information systems they were able to quickly establish that the salmonella originated on the farm and avoided recalling multiple related feed batches, as would have been done prior to traceability. Navobi conducted an *ex post* assessment of the cost

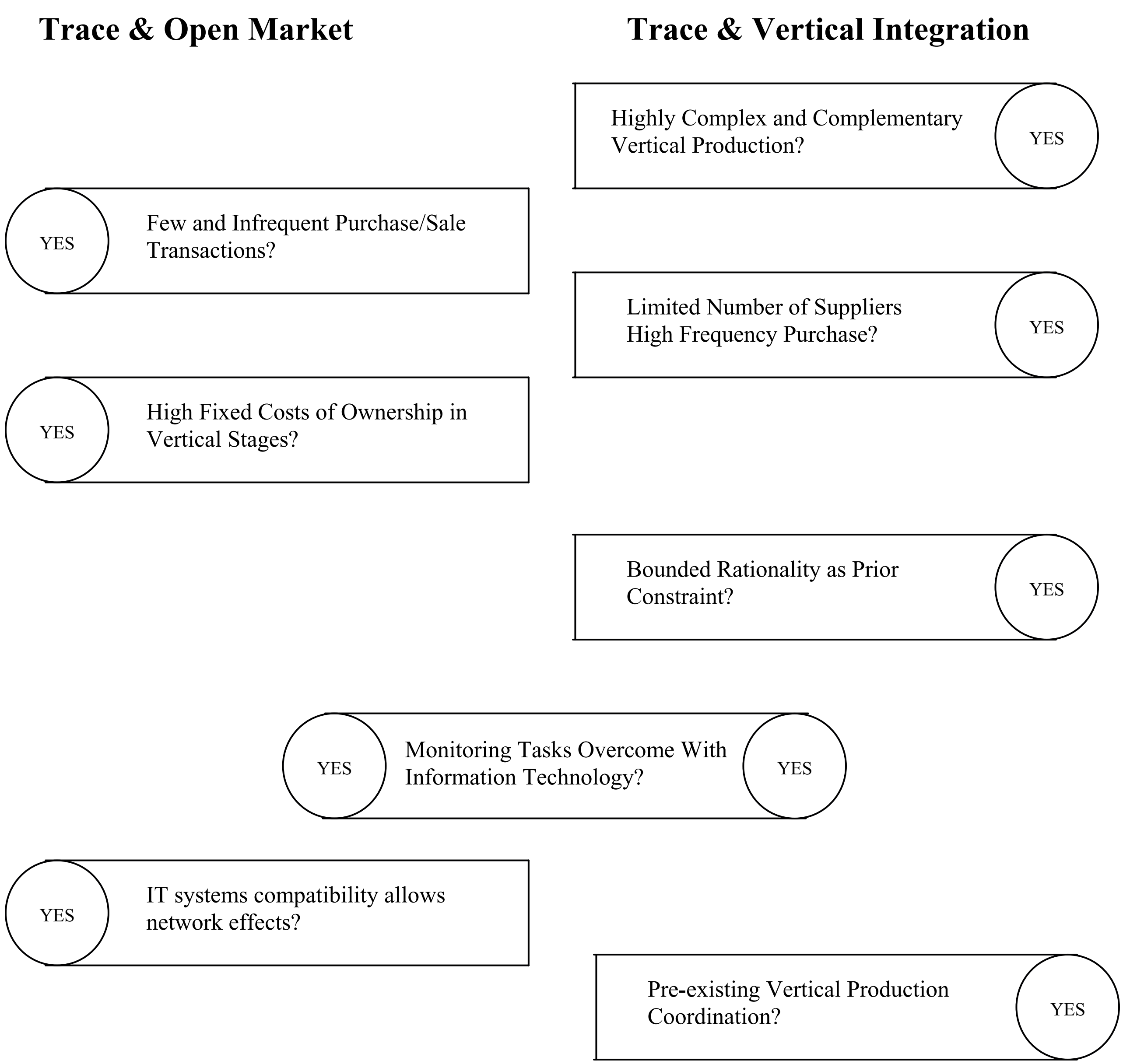


Figure 4. Balance of The Decision Process for Traceability Within The Spectrum of Open Markets and Vertically Integrated Firms.

savings from traceability in this circumstance and estimated that in this single instance they saved over $100,000 in recalls and recovery costs.

Participants suggested that valuation of traceability in a food-safety context depends on the accuracy of testing and sampling procedures for detecting contamination, the costs of sampling and testing or control (HACCP) procedures, the dispersion of the product once it leaves the control of the firm, the probability of contamination itself, the costs of recall, and any potential costs in terms of liability and reputation damage. Traceability reduces the costs of recovering from a food contamination event and may reduce the probability of outbreak by improving information within the process by allowing for rapid identification and communication of potential issues among participants.

Conclusions

The primary objective of this research is to describe the implementation of traceability and information systems in the meat and poultry sector of Europe in order to gain insights into the economic implications of traceability and the information technologies on inter-firm information exchange and organization. The intention is to clarify the economic reasons for traceability and provide guidance as U.S. firms consider implementing traceability systems.

Traceability is often proposed primarily to overcome the perceived information asymmetry between the final product handler and the consumer. However, this fails to consider that branding and product labeling can offer remedies for information asymmetry. The more likely reason for implementing traceability is to reduce the information asymmetry within the supply chain. Therefore, the incentives to adopt traceability depend on the level of inherent production uncertainty and the uncertainty created by moral hazard and opportunism, the observability of traits, monitoring costs with and without adoption of traceability technologies, and the extent of control the firm can have over these processes. The volume of production, the nature of aggregation and disaggregation in the supply chain, and the scale compatibilities between vertically adjacent stages will influence the extent of control. In general, the simpler the physical logistic control problem, the controllability, and observability of traits and inputs, the less valuable traceability might be within the supply chain.

In the traditional theory of the firm literature, vertical contracting and ownership are alternative solutions to product labeling, repeat purchasing, and certifying as mechanisms to solve information asymmetry. Vertical coordination does so by removing the market interface that creates the information asymmetry. However, traceability and specifically Internet-based information systems also have the potential to reduce information asymmetry through reductions in monitoring costs, improved information exchange, greater quality control, and even reduced agency costs when coupled with hardware measuring technologies which interface directly with the information system. This information-technology change at the inter-firm market level has the potential to alter transactions costs and therefore to influence decisions regarding inter-firm organization. The European cases all support the notion that vertical integration and coordination is complementary to traceability. The supply chains which have implemented traceability have tightly controlled vertical production systems even with the adoption of Internet technologies. However, all have been implemented with the past five years, so that as firms learn more about utilizing the information systems they may evolve into more market-oriented structures. Traceability and information technology are stepping into an already complex restructuring of meat supply chains in the U.S. and will further alter incentives and strategies to vertically coordinate, integrate, or even return to more open markets. Evidence presented from previous research and the European cases suggests that traceability information systems will lead to tighter vertical relationships and more hierarchical governance structures.

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