Traceability in the U.S. Food Supply: An Application of Transaction Cost Analysis

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Abstract:

Suboptimal supply of food and agricultural traceability is framed in a transaction cost analysis. We propose a model that considers the variables of opportunism potential, agency costs, uncertainty, asset specificity, frequency, and transaction costs. The model is then applied to the development of a typology of feasible governance modes – market, hybrid, firm, or public bureau, considering levels of transaction costs and competencies of private firms. Theoretical and practical implications are discussed and future research opportunities are suggested.

Subject code: Traceability supply, transaction cost economics, agency theory.

Introduction

Modern food and agribusiness supply chains in the U.S. are characterized by their efficiency-driven trends. In general, food and agricultural products are income inelastic in nature. Consumer spending on such products has changed less proportionally as income rises. This phenomenon causes the so called “farm problem”. In essence, farms and food companies are constantly facing declining profits, while an invisible price ceiling exists for their products but some of the input costs keep pace with income. Vertical integration, standardization in products, and global sourcing for low-cost inputs are then the three major approaches to secure margins. These three forces interact and result in consolidation in operations. Firms that are vertically integrated enjoy scale economies in unit fixed cost allocation, in marketing standardized products, and in global operations. However, as Coase (1937) prescribed, costs of errors outweigh the gains when firms over stretch their boundaries beyond management capacity.

Bovine Spongiform Encephalopathy (Beef), hoof-and-mouth disease (pork), microbial contamination of fresh produce (Spinach), poisons in animal feeds (Chinese pet food), unhealthy food additives (Chinese dairy products) and genetically modified organism (GMO) products are a few in the long list of food safety events that draw public attention. During a food safety outbreak, all companies in the industry can be impacted from loss of sales. For example, the E Coli outbreak from fresh spinach in 2006 has caused a change in consumption preferences. Even after processors in California formed an industrial association, California Leafy Green Products Handler Marketing Association (LGMA) to control quality and boost public confidence, U.S. consumers have still purchased less spinach. In a worst scenario, public trust in the capability and integrity of the industry could be so low that a market collapse would result, leading to a deadweight loss of the whole society.

While both private and public sectors in the U.S. are aware of the severity of the problem, and recognize that traceability is the first step of the food supply chain quality management (Roth el al., 2008), market failure becomes an obstacle in the supply of traceability. The public sector is not efficient in identifying and tracing all various use cases (Golan et al., 2004) but the private sector does not have sufficient incentive to cover the gaps (Richards et al., 2008). According to Arrow (1969), “Market failure is not absolute; it is better to consider a broader category, that of transaction costs, which in general impede and in particular cases completely block the formation of markets”. In this paper, we apply Williamson’s (1998) transaction cost framework in the food and agricultural industry and analyze the problem of insufficient traceability supply. The paper is organized in four sections. First, a brief introduction to food traceability supply is presented. Second, a literature review on transaction cost economics is conducted. Third, a synthesis of the theories and a model are proposed. Fourth, a typology of governance modes and policy implications are discussed.

Traceability in food supply

International Organization of Standardization (ISO 8402:1994) defines traceability as “the ability to trace the history, application or location of an entity by means of recorded identifications”. The Food and Agriculture Organization of the United Nations (FAO) includes a dynamic aspect in the Codex Alimentarius (Lain for food code): “traceability/product tracing is the ability to follow the movement of food through specified stage(s) of production, processing and distribution”. European Community Regulation 178/2002 offers a definition more pertinent to food and agribusiness in details: “the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution". Modern food and agribusiness supply involves interdependent actors and numerous inputs, processes, and outputs. In order to be effective, "traceability must be managed by setting up a traceability system" (Moe, 1998), which constitutes a record keeping system designed to track the flow of product or product attributes through not only internal production processes but also external supply chains (Golan et al., 2004). In this context, the concept of traceability incorporates a supply chain view. Under which, transactions (i.e., exchange relationships between consumers and suppliers) are sustained by interactions of three activities – flows of physical products, flows of information, and flows of financial rewards – in a symbiotic cycle. Traceability systems along supply chains operationalize on the dimension of information, emphasizing on five factors – *what* (unit of analysis), *who* (actors), *where* (locations), *when* (events), and *how* (methods) of a subject under considerations.

Van Dorp (2002) defines a traceability system from the perspective of information management, including three layers: *item coding* (the physical layer), *information architecture* (information layer), and *planning and control* (the control layer). Item coding identifies products' unique properties, such as forms, fits, or functions, and embeds them in codes. This activity establishes a link between a product and associated information to increase the efficiency of the system. Information architecture manages the flow of information in terms of quantity and quality by setting up de-coupling points in the supply chain to determine the degree of aggregation of information, and assures information quality through quality audits and certification. The two levels build a foundation for the third, planning and control, which optimizes production activities with respect to feedback from tracking activities.

Traceability costs arise from activities of these three layers. First, costs of product differentiation relate to managing an item coding system that enables tacking units to be separated from one another and preserved their unique identities. Second, costs of recordkeeping relate to managing the information architecture that collects and maintains information on products and product attributes. Depending on the objectives of a system, these activities vary in the degree of sophistication, resulting in the characteristics which we can observe from a traceability system: the *breadth*, which describes the amount of information the system records; the *depth*, which defines how far back or forward the system tracks in a supply chain; and the *precision*, which reflects the degree of assurance a system can specify a particular product movement or characteristic.

Suppliers have three general objectives to develop and maintain traceability systems. First, a system is designed to improve supply management. By tracking production, inventory, and sales, a system provides information for finding the most efficient approach to coordinate logistics activities. Second, a system is designed to assure quality management. By tracking product movements, a system isolates the sources of potential hazards, clarifies liability, and limits the extent of risk associated with a food safety failure. Third, a system is designed to facilitate marketing management. By tracking product attributes desired by consumers, a system differentiates among products and creates new market opportunities. Suppliers are thus able to attain higher profits, cost-wise, from business environment with lower costs and less risk; and, revenue-wise, from a market position with better margins. An economically justifiable amount of investment on a traceability system is then determined by estimating and weighing the benefits that the system can bring to the company (Golan et al, 2004).

Traceability and technology

Food and agribusiness companies have spent substantial efforts in improving traceability technology. In the product identification technology, for example, the Universal Product Code (UPC), or the bar code, is a labeling scheme based on standards set up by the Uniform Code Council (UCC) of the U.S. and European Article Numbering (EAN) System. It contains a series of 12-digit or 14-digit numbers that represent certain attributes of a tracking unit. While it is a widely adopted industrial practice and the cost of application is low, it has very limited capacity for storing information. Moreover, retrieving data requires scanning the label with a bar code reader, which may not function well in a wet and cold environment. The radio frequency identification (RFID) is a newer technology without these two limitations. Based on the standard, Electronic Product Code (EPC) set up by the UCC and EAN, a RFID tag embeds a computer chip and its own power source so that it can actively and automatically receive and send a large amount of data. In addition, the tag can be recycled, reprogrammed, and reused for lowering costs. One potential drawback is that RFID tags can only be read by machines and cannot be processed manually by humans, and therefore makes the investment in a reliable RFID system utmost important (Thompson et al., 2005). Other technological development in quality and safety measurement, genetic analysis, environmental monitoring, geospatial positioning, and software for system integration are becoming practical industrial applications (Opara, 2003).

Economics of traceability problems

In the U.S., while private food and agribusiness companies have developed a significant capacity, they may not be motivated to improve traceability to a socially optimal level without incentives – a case of market failures (Golan et al., 2004). Extant economic literatures address causes of market failures from two aspects: information asymmetry and public goods. Taking the previously mentioned supply chain view, information can be transformed and incorporated as a part of product specifications. A market-based solution can then be devised by balancing product offerings and financial rewards. Although the value of anonymity (Golan et al., 2004) raises an issue of moral hazard, the principal agent model is applicable. However, the impact from monitoring costs would attenuate the effort and cause deviations from the status of optimal traceability supply. Further, traceability has a characteristic of public goods (Richards et al., 2009). Traceability supply may suffer from a free rider problem, resulting in reverse selection. A mandatory traceability system is a standard government response to this problem. However, it is criticized to be ineffective, failing to accommodate various use cases in different industrial sectors. The current public budget constraint does not welcome the development of a costly, fully encompassing system.

Market-based solution for traceability problems

Suppliers of homogenous products in a competitive market receive from consumers a fixed amount of payment, α, in each unit of sales, because consumers are unable to distinguish between products. Suppose some consumers are willing to pay amount P to suppliers of differentiated products. Let $P = \alpha + \beta b$, where

b: consumer perceived differentiated product attributes

β: a measure of consumers' willingness to pay for the differentiated attributes

And βb represents the added value of the differentiated attributes relative to the homogenous products. Producing differentiated attributes incurs additional costs c(x) to suppliers. Suppliers then hold a profit function: $\alpha + \beta b - c(x)$. Market incentives for tracing the differentiated attributes can be distinguished into three scenarios.

1. $\beta = 0$: Consumers do not value the differentiated attributes. Since consumers are not willing to pay for traceability, a market-based solution is not feasible in this scenario.

2. $\beta > 0$, but $\beta b > c(x)$: Consumers are willing to pay for the differentiated attributes, and market incentives are greater than traceability costs. The market itself can function well for this type of transactions.
3. $\beta > 0$, but $\beta b <= c(x)$: Although consumers are willing to pay for the differentiated attributes, the market fails to fulfill demand. Traceability supply is not economically justifiable, unless βb increases, or $c(x)$ decreases.

<u>Market incentives for traceable attributes</u>

Consumers perceive differentiated attributes through product signals. In reality, the relationship between product signals and true product attributes is not deterministic. Let

$b=M(x,e)$, where

$M(x,e)$: signals of differentiated product attributes.

x: true product attributes, which may be unobservable to consumers.

e: a random noise, assuming $e \sim N(0,\sigma^2)$

Suppliers of differentiated products receive profits:

$Y = \alpha + \beta M(x,e) – c(x)$

The profits are maximized as the optimal level of x is chosen, under the first-order condition

$\beta M_x – c'(x) = 0$

The optimal level of product attributes x* is implicitly defined as $x^*=x^*(\beta, e)$, and comparative statics $\partial x^*/ \partial \beta = -Mx / \beta M_{xx} – c''$, which is positive definite.

Assuming both consumers and suppliers are risk-neutral, consumers maximize their expected value from purchasing products with differentiated attributes. Let

$E[B(x,e) - \alpha - \beta M(x,e)]$,

subject to (1) $E[\alpha + \beta M(x,e) - c(x)] = u_0$; and (2) $x = x^*(\beta, e)$

where:

B(x,e): consumers' benefits from the differentiated attributes.

u_0: suppliers' reservation utility level

The first-order condition to maximize the constrained objective function equals to:

$E[(B_x – C') \partial x^*/ \partial \beta] = 0$

Substitute results from suppliers' profit maximization and take a second-order Taylor approximation of M and C, we can derive an expression of β*.

$\beta^* = E[(B_x)^*(M_x)] / E[(M_x)^*(M_x)] = Cov(B_x, M_x) / Var(M_x)$

Therefore, consumers' willingness to pay for the differentiated attributes is influenced positively by the correlation between consumers' benefits and product signals, and negatively by the disturbances of the product signals, in other words, goal congruence and performance ambiguity.

Assuming b is a linear function of M(x), so b = M(x) + e. Consumers and suppliers are both risk neutral. Suppliers have a utility function, $U = E(Y) – var(Y) = \alpha + \beta M(x) – c(x) –\beta^2\sigma^2$. Consumers pay β to maximize their expected value from the differentiated product attributes. Maximize $-\alpha + (1-\beta)M(x)$; and subject to (1) $\alpha + \beta M(x) – c(x) –\beta^2\sigma^2 = u_0$; (2) $x=x^*(\beta)$. We can find the optimal market incentive (β*) from the first-order condition and assure the value maximization in the second-order condition. Let M(x) = px, and $C(x) = cx^2$, where p and c respectively measures the unit profit margins and variable costs suppliers received from signalling differentiated product attributes. The comparative-static analysis indicates relationships between parameters and market incentives -- market incentives are positively influenced by consumer perceived values ($\partial\beta^*/ \partial p>0$), while negatively impacted by traceability costs ($\partial\beta^*/ \partial c <0$) and by disturbances on market signals ($\partial\beta^*/ \partial\sigma^2<0$). Current researches on traceability problems in general study market-based solutions through these relationships. The marketing approach emphasizes on product positioning and consumer behaviors to raise consumer perceived values. The industrial engineering approach resorts to process and technological improvements to reduce traceability costs. The transaction cost approach focuses on exchange relationships between consumers and suppliers and acts on the other factor, disturbances, or, uncertainty.

Review of transaction cost economics

Transaction costs

A transaction occurs when a product or service is transferred through an interface between two separate parties. Ideally, the product or service moves smoothly with a constant full speed. The neoclassical economic theory portrays such a frictionless business environment. A firm is regarded as a production function that selects through alternatives to minimize input costs and maximize consumer utility. The invisible hand, the price mechanism, coordinates all consumers, firms, and economic activities moving toward an optimized status of equilibrium, so that the market is looked like "ocean of unconscious cooperation". However, this ideal is not always true. In reality, as Coase (1937) pondered the justification of "islands of conscious power", he argued that there are frictions – costs of using the price mechanism, named as transaction costs. In Coase's ideas, to organize production through the price mechanism, an actor needs to first discover relevant prices in the market, and then negotiate and conclude a contract with another actor for each exchange transaction. It is costly to conduct these two activities. Thus, a firm is formed to allow an authority to direct resources, saving the costs of marketing. However, organizing firms is not a panacea either. The expansion of a firm is subject to two forces. First, the size of a firm is constrained by diminishing returns of management, because costs of errors increase as a firm grows. Second, in a competitive environment, a firm takes over an activity from another firm only if the cost of running an operation internally is less than the cost of acquiring the same outcome of the operation from the market. The boundary of a firm thus is determined by a tradeoff between the two sources of transaction costs. In addition to cost comparisons, the presence of uncertainty, "the fact of ignorance and the necessity of acting upon opinion rather than knowledge", makes a firm more effective than the price mechanism. While Coase pointed out the needs for forecasting and an inevitable process of cephalization under uncertainty, he left the sources and implications of this effect for future researches.

Transaction cost economics

Following Coase's (1937) idea that a firm has coordinating potential to tradeoff transaction costs, Williamson (1998, 1981, 1979, 1971) developed a micro-level analytical structure for transaction cost economics and offers a more extensive understanding of the topic. The foundation of Williamson's framework is built on two behavioral assumptions, based on Herbert Simon's (1979) studies on human nature. (1) Bounded rationality describes the limited competence of human actors to formulate and solve complex problems and to process information. While bounded rationality is not necessarily hyperrationality, it does not mean irrationality either. Human agents are intended to be rational, farsighted, rather than myopic, although, in an economic sense, all complex contracts are still inevitably incomplete, containing gaps, errors, or omissions. (2) Opportunism is viewed by Williamson as the central concept in the study of transaction costs. Human actors are assumed to be self-seeking with guile, not only pursuing self-interest but also applying false or empty threats or promises to take advantage of others if an opportunity to gain more profits is present. Accordingly, a contract without a credible endorsement will not be self-fulfilled.

In this framework, the transaction is the basic unit of analysis. The operationalization of the transaction cost economics is based on principal dimensions, asset specificity, uncertainty, and frequency, the three key features of a transaction. *Uncertainty* signifies the disturbances to which transactions are subject. *Frequency* indicates whether and how transactions recur. *Asset specificity* represents the degree to which durable transaction-specific investments are incurred. The transaction-specific assets take various forms, such as physical assets, human assets, site specificity, and dedicated assets, etc. Under this analytical framework, a firm serves a role not only as a production function transforming inputs into outputs, but also as a structure governing transactions. Given bounded rationality and opportunism, a firm acts on the three transactional dimensions, with an objective to set up order in an exchange relationship, mitigate potential conflict threats, and thus realize mutual gains. This objective is achieved by selecting the appropriate governance mode from discrete structural alternatives – market, hybrid, or hierarchy.

The governance modes differ in their competence, in terms of adaptability, incentive intensity, and control instruments (Table 1). Contingent to the institutional environment, the efficacious governance mode economizes transaction costs and better support exchanges.

Insert Table 1 about here

Insert Figure 1 about here

A transaction cost analysis on traceability problems

Transaction cost economics focuses on an exchange relationship between two or more parties and regard economizing on transaction costs as the main purpose of an analysis. This can be accomplished by mitigating bounded rationality and opportunism of both parties involved. In the original model setting, as transactions already exist and function on a regular basis, implementation of transaction cost economics starts from analyzing the three key features of the transaction in order to determine the right governance structure for the economic issue at hand. The governance structure sets a firm's boundaries. The decision is an important one, because in a world of transaction costs and incomplete contracts, "the boundaries of a firm matter in that these boundaries determine who owns and controls which assets" (Hart, 1989), and it is "the way in which internal relations are ordered" (Williamson, 1981). However, in the context of our research question, a desired transaction currently does not exist -- market failures due to high transaction costs hinder traceability supply. A transaction cost analysis is thus exercised in a reverse order. In accordance with Williamson's (1983) proposition, "governance structures need to be matched to the underlying attributes of transactions in a discriminating way if efficiency purposes of economic organization are to be realized", we argue that government interventions on contextually relevant transaction attributes so as to establish market safeguards are the key to induce transactions of traceability, a market-based solution for traceability problems.

Uncertainty

Uncertainty is a multidimensional construct and arises from different sources and perspectives. For example, Koopmans (1957) distinguished between primary and secondary uncertainty while Milliken (1987) defined a typology of uncertainty dimensions as state, effect, and response uncertainty. Additionally, Sutcliffe and Zaheer (1998) tested three sources of uncertainty in a transaction, primary, competitive, and supplier uncertainty. Although empirical studies from John and Weitz (1988) and Heide and John (1990) found that other types of uncertainty, such as volume, or technological uncertainty, have effects on firms' vertical integration decisions, in the context of a transactional relationship, Williamson (1998) contends that the behavioral uncertainty is the relevant form, as it is human actors' behaviors, including how they initiate or respond to different types of changes, that impact transaction costs. While bounded rationality causes all contracts to be incomplete, opportunism subjects them to hazardous results. The effects of these two characteristics may come from all human actors involved in the transaction; for example, both suppliers and customers, or even other suppliers and customers who are currently not involved but have the potential to influence the transaction.

1) *Goal congruence*:

Sources of uncertainty are explained by goal congruence between consumers and suppliers and performance ambiguity of suppliers, the two dimensions derived from the previous analyses, implying root causes of high transaction costs. Goal congruence determines whether consumers and suppliers can establish an equal and mutually beneficial agreement. Are consumers and suppliers maximizing their joint utility, or pursuing their own sub-goals at the expense of the other party? Conflicts between the goals of two parties can arise for several reasons. In terms of morality, consumers and suppliers may hold different moral and value standards and exhibit Williamson's (1998) behavioral assumption, opportunism as self seeking with guile, pursuing own interests at the expense of other parties. In terms of information, information asymmetry may exist and thus cause transaction parties unable to acquire necessary information for making correct decisions. In terms of competency, suppliers fail to fulfill their promises to consumers, or even worse, are not capable of meeting customer requirements. Consumers may not be equipped with the necessary knowledge or skills to perceive or process market signals sent by suppliers.

In terms of market structure, competitive conditions and market power may also explain conflicts between suppliers and consumers. For example, suppliers under an over-crowding market may deviate from consumers' benefits in order to survive cut throat competitions.

Moreover, suppliers or consumers with market power may exercise their power to achieve better trade terms.

Insert Table 2 about here
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2) *Performance ambiguity*:

Referred to classification schemes of Nelson (1970) and Darby and Karni (1973), common food and agribusiness products can be categorized into three types according to their *search*, *experience*, or *credence* attributes. While consumers can examine a product's search attributes before purchase or experience attributes after consumption, it is impossible for them to discern credence attributes, because they simply do not have the necessary capacity and capability to monitor production processes or to detect properties in the product content. Differences between the three product attributes suggest the amount of supply information hidden from consumers, implying the degree of information asymmetry and thus potential hazards to which transactions are exposed.

Insert Table 3 about here

<u>Asset specificity</u>

Investment in transaction-specific assets implies two characteristics of traceability supply.

1) *Information effects*:

Efficient processing of information is an important and related concept in transaction cost economics (Williamson, 1979), because human actors make decisions – assessing situations, forming expectations, selecting choices, and evaluating outcomes, based on their perceived information, information available to them at the time of decision making and their interpretation of the available information. On the one hand, bounded rationality constrains human actors' abilities to receive, store, retrieve, and process data. When they encounter complex and uncertain transactional conditions, this limitation causes an effect of "information impactedness". Information sticks to the source and does not transmit freely, because information receivers are unable to process it. Moreover, observational economics show that "the acquisition of information often involves a set-up cost" (Radner, 1970), a fixed cost in nature. This minimum cost threshold represents the costs of information search, which is independent of the scale of demand, often causing the acquisition of information less economically justifiable and intensifying the problem of bounded rationality. Furthermore, it takes efforts and costs to coordinate different human actors, a problem Williamson termed as "convergence of expectations". Especially in a highly variable and uncertain environment, in terms of higher levels of bounded rationality and opportunism, it may require constant communications and negotiations. High coordination costs may cause information processing prohibitive. On the other hand, bounded rationality can be countered by investing in "unsticking" information (von Hippel, 1994), such as expert system or a user-friendly computer database. Although the human nature of bounded rationality still makes all contracts incomplete, the investment in information assets enables human actors to be more farsighted, alleviating the degree of cognitive limitation. As information is less costly and information processing is more convenient, more information is available and increases the probability to detect opportunistic behaviors.

2) *Interdependency*:

A transaction involving specific assets is referred as an idiosyncratic transaction. In idiosyncratic transactions, investment in assets only for certain customers' usages incurs non-marketable expenses and cost-bearing consequences. The degree of asset specificity impacts the relationships between transactional parties, specifically, increasing the degree of interdependency. Therefore, asset specificity locks both parties in the transaction. On the one hand, interdependency breeds potential hazards in the transaction. Bounded rationality makes it prohibitive to devise an inclusive contract to cover all possible scenarios. Hence, both parties can only agree on general terms of trade first and negotiate for contingent adjustments in the future. However, opportunism may urge transactional parties to exploit economic surplus from other parties, when there is an opportunity, until the perceived marginal net benefits of other parties are reduced to zero. This effect from opportunism under conditions of contract incompleteness would result in constant bargaining and haggling between transactional parties as they are tied in the transaction and cannot walk away, increasing transaction costs. On the other hand, by definition of "transaction-specific", suppliers cannot apply the assets for other purposes. Customers cannot either switch to other suppliers for a favorable deal with products or services in the same specifications, because production by using non-specific assets generates higher costs. Therefore, when the degree of asset specificity is high, both transactional parties may be willing to commit to the continuity of their exchange relationships, decreasing transaction costs. From this perspective, specific assets act as "hostages" of transaction parties, bringing in credible commitments to support transactions. The efficacy of government interventions in correcting market failures therefore lies in the economics to transform specific asset investment from threats to commitments of parties under transactions. As Williamson (1983) comments, "failure to recognize the economic purposes served by hostages has been responsible for repeated policy error".

Frequency

As suppliers' credible commitments promote exchanges, frequency of transactions thus serves as the dependent variable of the model. Asset specificity mitigates the effect of uncertainty and influences the frequency of transactions in two aspects.

1) *Frequency and information effects*:

Familiarity brings communication economics. When contractual parties transact frequently, more interactions can generate learning effects in information processing. Example of this include, developing specialized languages and codes, being more efficient in normal operation procedures, or reducing the degree of impactedness and coordination costs. Further, as the costs of information collection are a fixed cost in nature, allocated unit cost is lower in a recurrent transaction, resulting in transaction specific savings in observational economics.

2) *Frequency and interdependency*:

Recurrent transactions are a necessary condition for an interdependent contractual relationship. Without assurance of continuing transactions, a supplier would not be willing to invest in or develop transaction specific assets, unless the expenses can be fully covered by customers in limited transactions, not a usual case. Higher frequency of transactions brings familiarity to contractual parties at the interfaces in which human actors in charge of operations interact with one another more often, and thus can build personal trust in relationships. As the level of trust increases, personal integrity may suppress opportunism and then reduce the degree of uncertainty. Moreover, recurrent transactions act as infinite repeated games in the game theory. Each contractual party is motivated to maintain goodwill in hope for future profits, because the probability for opportunistic behaviors to be detected is higher in repeated games than that in one-shot games. Therefore, opportunism and potential moral hazards are curbed. Contractual parties can form more constructive engagements, avoiding suboptimal bargaining and haggling and resulting in effective adaptations.

Figure 2 illustrates the relationships among the above-mentioned key variables of the model. Goal congruence and performance ambiguity contribute to the degree of uncertainty in a transactional environment. While uncertainty serves as the most influential attribute predicting the lack of transactions of traceability, asset specificity, under certain market conditions, being viewed as credible commitments rather than a threat to the vulnerability, functions as a complex moderator (Igbaria, Parasuraman, and Badawy, 1994), exhibiting both ex ante (screening) and ex post (bonding) effects, and promotes exchanges. The efficacy of the investment in traceability assets is then observed through changes in the frequency of transactions. The relationships of variables are summarized as follows.

Proposition 1: Goal congruence is negatively related to uncertainty.

Proposition 2: Performance ambiguity is positively related to uncertainty.

Proposition 3: Asset specificity moderates the relationship between goal congruence and uncertainty such that when asset specificity is high, the relationship is stronger than when asset specificity is low.

Proposition 4: Asset specificity moderates the relationship between performance ambiguity and uncertainty such that when asset specificity is high, the relationship is weaker than when asset specificity is low.

Proposition 5: Uncertainty is negatively related to frequency.

Proposition 6: Asset specificity moderates the relationship between uncertainty and frequency such that when asset specificity is high, the relationship is weaker than when asset specificity is low.

Insert Figure 2 about here

Policy implications

The implementation of transaction cost economics follows the contingency approach – efficient governance modes vary depending on environments in which transactions are embedded. Table 4 depicts a typology of four scenarios based on the level of goal congruence and performance ambiguity. The characteristics of these two drivers signify solutions for traceability problems in two perspectives. First, through proper alignment between transactional contexts and organizational control mechanisms – specifically, social and informational underpinnings (Ouchi, 1979), the public agency can alleviate or remove obstacles on market incentives and promote traceability supply. Second, in general, a traceability system monitors or measures supplier behaviors or outputs of those behaviors. The effectiveness of measurements is determined not only by traceability methods but also by the nature of transactions, as a measurement of transactions with low performance ambiguity would be less accurate. Thus, a proper choice of traceability objects on behaviors, outputs, or both, impacts the efficacy of the public interventions.

Scenario 1 characterizes a situation of low performance ambiguity and high goal congruence. Consumers can easily verify products through search attributes. Moreover, consumers and suppliers have converged expectations. Under these conditions, price mechanisms can function well, and the market is the most efficient governance mode. Government interventions would create unnecessary spending and instead reduce market efficiency. No government action is needed.

Scenario 2 describes interactions of low performance ambiguity but low goal congruence. The low level of performance ambiguity implies that consumers would already access sufficient information for their purchasing decisions, and do not have difficulty in verifying product attributes or monitoring production processes through search or experience attributes. However, consumers and suppliers hold different values, standards, or knowledge on product specifications. Under this condition, mechanisms to facilitate converged expectations between consumers and suppliers improve efficiency of transactions. Low performance ambiguity implies output measures can be efficient and effective in traceability design. The public agency can focus on solutions of the social aspect – for example, setting up rules and regulations of markets, promoting consumer education, or requiring supplier training and qualifications, etc, delegating responsibility to consumers and suppliers, a more efficient approach than a full-scale involvement.

Scenario 3 depicts transactions with high performance ambiguity but high goal congruence. While suppliers and consumers share similar goals, high performance ambiguity hinders mutual understanding of the two parties in transactions. On the one hand, suppliers are not able to acquire sufficient information to locate consumers or understand demand requirements. On the other hand, consumers may not access product or production information. Although the two parties may not exhibit opportunistic characters, a lack of information still breeds uncertainty and could inhibit market formation or growth. In this case, informational remedy is the focus. The public agency can provide standards and incentives for the private sector to develop information systems, including market signals and related supporting mechanisms. High performance ambiguity implies that tracing outputs can be ineffective and inefficient. Thus, traceability activities should emphasize more on behavioral measures.

Scenario 4 is characterized by high performance ambiguity and low goal congruence. Product, production, and markets are complex, and transactions are subject to hazards of opportunism. In this condition, transaction costs are at the highest level. A traceability system will reply more on behavioral measures for supplier selection and qualification, since high performance ambiguity would cause output measures ineffective, and low goal congruence could increase monitoring costs. Nevertheless, as implied by the current issues of mandatory traceability systems (Golan et al. 2004), informational remedy, such as coding systems and information architecture, is only a partial solution and could result in unexpected effects from gaming and rent-seeking behaviors. Social remedy alone is not sufficient, either, because it is not capable of reducing uncertainty perceived by consumers and thus unable to support market-based solutions. Therefore, an integrated approach of both social and informational remedies is necessary. In this case more must be done by the organization in order for both parties to effectively interact. Implementation of high performance work systems could work to communicate to both internal and external customers a commitment to quality thereby enhancing performance ambiguity and goal congruence. High performance work systems involve particular configurations of work structures, practices, and processes. Workflow is organized around key business processes and often involves teams to carry out those processes. High performance work systems also include a number of human resource policies and practices (e.g., hiring, training, performance management, compensation) aimed at enhancing employee skills, knowledge, motivation, and flexibility (Gephart and VanBuren, 1996). Successful organizations have instituted programs such as total quality management, employee involvement, job enrichment, skill-based pay, autonomous work teams, and gainsharing plans (Lawler, Mohrman, & Ledford, 1992). The goal of these and many other "win-win" interventions is to increase firm performance by positively affecting employee behavior on the job in order to provide the best possible products to consumers.

Insert Table 4 about here

Concluding remarks

In a transaction cost analysis, insufficient traceability supply is attributed to high level of uncertainty driven by goal congruence and performance ambiguity. Asset specificity can be viewed as credible commitments, moderating negative impacts from uncertainty by screening and bonding effects. Reductions in transactions costs can be observed through increase in transaction frequency. The public agency corrects market failures through social and informational approaches. The efficacy of public interventions is contingent to the fit between strategies and environments of traceability systems.

The concept of high performance work system (HPWS) from human resource management provides an alternative view for developing an integrated management system and promoting traceability supply. HPWS design must be guided by a specific set of design principles that aim at attainment of "fit" between the organization and its external business environment. HPWS design should not be focused solely on individual high performance practices but more so on a design that considers the customer and the organization's external business environment (Farias and Verma, 1998). HPWS designs optimize the needs of the people in the organization as well as demands of the technical system. This *socio-technical* perspective has much application for the current traceability issue discussed above. A socio-technical approach necessarily emphasizes the interrelatedness of the functioning of the social *and* technological subsystems of the organization and the relation of the organization as a whole to the environment in which it operates (Trist, 1967).Current discussions on traceability supply pay more attention on traceability technologies and the informational aspect of the problem. From the policy perspective, omit the social aspect, which is at least as importance as its counterpart, would only cause traceability efforts more costly and less effective. After all, the ultimate goal of traceability systems is not to trace and track product and process attributes as detailed as possible, but rather to achieve cooperation between consumers and suppliers so as to improve food safety and promote societal welfare.

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Table 1. Attributes of alternative governance modes

Attribute / Mode	**Market**	**Hybrid**	**Hierarchy**
Adaptability	Low	Medium	High
Incentive intensity	High	Medium	Low
Control instruments	Low	Medium	High

Table 2. Causes of goal incongruence

Aspect/ Party	**Supplier**	**Consumer**
Morality	Suppliers intend to pursue sub-goals.	Consumers intend to pursue sub-goals.
Information	Suppliers do not access full consumer information.	Consumers do not access full product or process information.
Competency	Suppliers are not capable of fulfilling promises or demand.	Consumers are not capable of perceiving or interpreting market signals
Market structure	Over-competitions among suppliers	Power imbalance between consumers and suppliers

Table 3. Relationships of product attributes and uncertainty

Attribute/Characteristics	**Hidden information**	**Hazard potential**
Search	Low	Low
Experience	Medium	Medium
Credence	High	High

Table 4. Alternative governance mechanisms for traceability supply

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Goal congruence</td></tr>
<tr><td>High</td><td>Low</td></tr>
<tr><td rowspan="2">Performance ambiguity</td><td>Low</td><td><u>Scenario 1</u>
Market solution
Output measures</td><td><u>Scenario 2</u>
Social remedy
Output measures</td></tr>
<tr><td>High</td><td><u>Scenario 3</u>
Informational remedy
Behavioral measures</td><td><u>Scenario 4</u>
Social and informational remedy
Behavioral measures</td></tr>
</table>

Figure 1. A transaction cost analytical framework

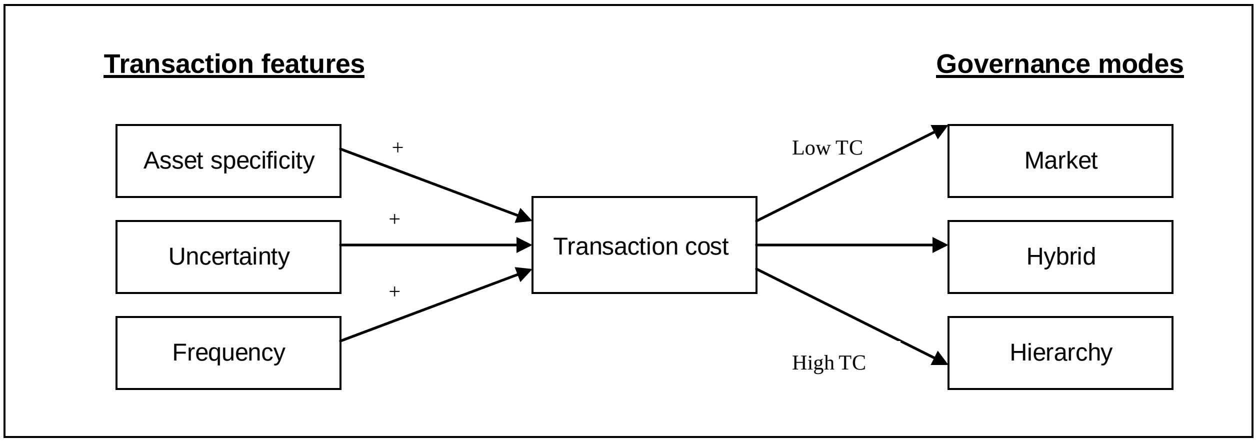

Figure 2. A transaction cost model for promoting traceability supply