Economic Evaluation of Food Traceability Systems through Reference Models

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Abstract

Food supply chains complexity present a real challenge to perform economic evaluation of food traceability systems and their innovation/upgrades. In order to perform a supply chain wide economic evaluation a conceptual framework is developed using food traceability reference models. Reference models allow interaction with chain members' requirements that come from legal and/or customer sources. The paper demonstrates how the requirements will have a definite effect on the costs and design of food traceability systems through the resources they demand. Even though this is a first step into addressing the challenge, more investigation is needed to clarify the boundaries of the two requirements and their economic effects on food traceability systems and their innovations/upgrades.

Keywords: *Food traceability, Food traceability systems, Reference models, Economic evaluation.*

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1. Introduction

The need for tighter control of inputs, materials and outputs led food companies to implement Food Traceability Systems (FTS) in the late 1980's. At that stage traceability was an element of Total Quality Control schemes aiming to improve warehouse management (Moe, 1998). As a result of a series of highly published food safety outbreaks in the European Union, supply chain wide FTS started to be required (Buhr, 2003; ECC, 2002; Fearne, 1998; García Martinez and Poole, 2004; Souza Monteiro and Caswell, 2006). Currently there are several supply chain wide FTS in place; however there is no economic framework to guide the development of new systems. Moreover, given the complexity of food supply chains, it is a real challenge to perform an economic evaluation of FTS and their upgrades. This will depend on the objectives of the FTS, the supply chain intra-firm and inter-firm infrastructure and organizational requirements, the compatibility of the system and other technological constrains, etc. For instance, if the objective is to trace the product back to its origin in less than a day, the type of FTS will be different from one aiming to ensure that a certain threshold of microbiological contamination is not surpassed.

According to Hobbs (2004), FTS can be designed either to improve the ability to quickly react to food safety hazards or to prevent them. The former is said to have an ex-post capability, while the later has an ex-ante capacity to manage food safety. The questions in either case is whether existing systems are adequate or whether upgrades are required for managing safety data; and whether both existing and upgraded systems present net benefits. An issue arises regarding the allocation of resources and the evaluation of the best way to design and implement a traceability system that meets all firms' objectives.
The paper aims to develop a framework using FTRM to evaluate the benefits and costs of traceability innovation in food supply chains. Particularly it focuses on the costs of a FTS innovation or upgrade. It uses Food Traceability Reference Models (FTRM) as the departing point to evaluate FTS. The costs are obtained by customizing the FTRM to each company' FTS requirement. Costs are a key factor in investment decisions, especially when performing an upgrade from legendary systems. Benefits can be added to the framework but are not explored within the present paper.
The paper is organized as follows: first, we define reference models and review the literature on its application to information systems design. Then we distinguish and discuss current work on the evaluation of FTS. The fourth section proposes a framework to evaluate alternative designs of FTS innovations based on reference models. Finally, we draw conclusions and propose further research

2. Reference Models

In order to understand Reference Models (RM), first information system architecture must be understood. A company' information system architecture can be described by a set of representations. Table 1 summarizes all possible representations of businesses information systems and sub-systems (Zachman, 1987):

- The owner' representation of the business: a description of all the processes and control points in the business.
- The designer' representation of the business: a description of the points where data is recorded.
- The builder' representation: all the problems where technology standards must be solved to record data.
- Out of context representation: all other representations used by other members of the company.
- Machine language representation: a representation in information language code.

All the representations allow a conceptual map of the final product that until recently was viewed as a one company product.

Table 1. Information systems architectures and reference models usefulness to develop products and systems

Generic	**Airplanes**	**Information systems**	**Internal FTS (Emphasis on safety)**	**Food supply chain traceability systems (Emphasis on safety)**
Ballpark	Concepts	Scope/objectives	Scope/objectives	Scope/objectives
Owner's representation	Work breakdown structure	Reference Model of the business	Reference Model of the business	Reference Model of the supply chain
Designer's representation	Engineering design/ bill-of materials	Data reference Models	Food Safety data reference model/ submodel of the Data reference model	Food Safety data reference sub-model from al Supply Chain members.
Builder's representation	Manufacturing engineering design/ bill-of materials	Technology reference model (technology constrained description)	Technology reference model (technology constrained description, including microbial and additives appraisal technologies)	Technology reference model (technology constrained description)
Out-of context representation	Assembly/fabrication drawings	Detailed description	Detailed description (Critical Control Point's maps and practices, microbial and additives appraisal practices).	Diagram of flow of goods, cross-docking processes and microbial appraisal points between members of the supply chain.
Machine language representation	Numerical code programs	Machine language description	Machine language description.	Machine language description for information sharing.
Product	Airplane	Internal Information system	Food safety internal information system	Supply chain safety assurance information system.

Source: Adapted from Zachman, 1987

Table 1 also adds the architecture representation for supply chains information sub-system. Here each owner's representation is considered private except for the points that relate all the members of the chain. The greater the coordination/integration of the supply chain, because of private incentives (co-innovating) or compliance incentives (co-regulating), the greater the number of actors involved on representations and therefore the higher the cost of the information system implementation[1]. However, as more firms in a supply chains link their data systems,

1. The costs (net benefits) of information system operation are lower (higher) as more firms within a supply chain learn how to share information with a traceability system. Thus, the greater the integration of supply chains the lower the costs of information systems operation, because of lower transaction and compatibility costs.

the easier would be to predict the pattern of information sharing. This creates pattern representation for business processes within supply chains. Once a pattern representation is possible, it only needs to be customized to the company requirements. Reference Models (RM) for supply chains are the result of that process.
A Reference Model (RM) can be defined as *“a model representing a class of domain. It is a conceptual framework that can be used as blueprint for information system development…”* (Fettke and Loos, 2006). This paper understands RM as universal solutions to solve a particular supply chain/business information problem.
A FTRM is a conceptual framework that can be used as blueprint for FTS development. FTRM are particular solutions (for an information system upgrade) to solve companies’ traceability information upgrade or innovation. FTRM are composed mainly by a business data module and sometimes they come with a best practice module. Business data module will contain a description of all the data identified and stored inside the information system of the company or service provider and their language code. Best practice module is a description of all the human practices performed by a company employee, within a location or time, to appraise or identify data.
In order to use FTRM to upgrade a FTS they have to be customized to the companies’ requirements. The exercise of customizing the FTRM to the company’s requirements will enable management to determine which data, system representations and practices are valid for the system upgrade and which are not. The requirements identified, as a result, can then be used to perform economic evaluation on projects for individual companies. Nowadays, the problem of economic evaluation is on supply chain level, especially when assessing the change from a legendary paper based system to a more automated one.
FTRM does not include technological upgrades, they are found when customizing the FTRM to the company requirement. Moreover, a FTRM does not address the reasons why a company should accommodate the internal practices to the FTS update. The proposed framework presented in this paper does not address these problems as it assumes that different management groups have a commitment in the food supply chain to adopt a particular technology and modify the internal practices within the companies to comply with the FTS upgrade. Yet, the proposed framework can be upgraded to include those factors.

3. Economic Evaluation of Food Traceability Systems

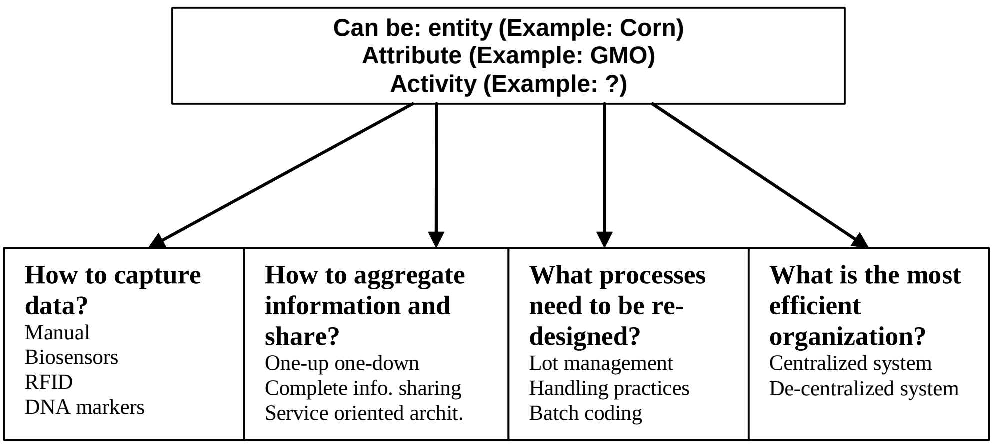
Over the last decade, food companies have introduced FTS as a way to manage safety and quality risk; to certify origin, authenticity and standards fulfilment; to coordinate supply chain; and to comply with the rule of law and with customers expectation (García Martinez and Poole, 2004; Hatanaka and Busch, 2008; Souza Monteiro and Caswell, 2004; Sparling et al., 2006; van Rijswijk et al., 2008). The decision to upgrade existing FTS or implement FTS innovations would depend on the net benefits they generate. The present paper proposes a framework that lies within economic engineering evaluation methods (Antle, 2000). Economic evaluation can be classified using three levels of standings: firm level (micro), supply chain level (meso) and society level (macro) (Fritz and Schiefer, 2008). The present paper does not analyze economic evaluation done neither on societal level nor firm level, even though the framework can be upgraded.
An example of what would be meso level evaluation is found at Golan et al. (2004) who present evidence of the benefits and costs of three supply chains by use of secondary information and several interviews but they do not fully perform economic evaluation. They conclude that in almost all analyzed supply chains the market is efficient balancing the cost and benefits of traceability systems. The authors use flow charts to describe the different supply chains. They do not go further in interpreting data requirements from the different companies and sectors analyzed given their heterogeneity. Disney et al. (2001) compare the economic efficiency of tracing back

to farm four different types of product destinations of pork and cattle when using two different traceability technologies (paper/ear tags) (8 simulation in total). The authors found, even aware of not recognizing all the benefits (i.e. savings in the costs of eradicating endemic diseases, gain in confidence in the livestock industry), a positive cost-benefit ratio for each simulation. Then, they simulate the economic effects of the different technologies to perform economic evaluation for famer-slaughter transactions.

Buhr (2003) presents conclusions of six case studies of companies that successfully deployed state-of-the-art FTS in Europe. One of the main conclusions is that producers must begin to consider how they can capture and control their own information to improve the value of traceability for their own situation. He does not try to evaluate how those conclusions are reached, yet he identifies some direct and hidden benefits of a FTS upgrade. Considering only costs on a micro level, Saa et al. (2005) simulated and compared the costs of three different FTS complying with EC No. 21/2004 for sheep and goat farm populations in Spain. They considered three strategies for traceability: (1) manual identification; (2) manual/RFID identification and (3) RFID identification. They found that a strategy that used manual/RFID identification was cost effective for farmers when considering an exception to the EC law; and was € 0.05 more expensive to manual identification when such exception was not considered. Yet, they neither include data gathering nor information sharing within their study.

The above studies did not evaluate the economic efficiency of the data requirements demanded by supply chain FTS. In this sense, Golan et al.(2004) show that it would depend on the dimension chosen by companies and within a supply chain. The dimensions of a FTS depend on the practice of traceability inside companies and within a supply chain. In this sense a firm or supply chain should first choose the objective of traceability defined in three dimensions: depth, breath and precision. Breath describes the amount of information the traceability system records. The depth of a traceability system is how far back or forward the system tracks. Precision reflects the degree of assurance with which the tracing system can pinpoint a particular food product movement or characteristic. After determining the objectives of the traceability systems, management should determine how to allocate the resources on the record-keeping system. They must decide: the type of data capture technology, data information aggregation and sharing options, process re-engineering and organizational change (Figure 1).

Figure 1
Decisions on resource allocation on Record-Keeping (traceability) systems



Source: Own elaboration

4. Using FTRM for Economic Evaluation of FTS

A FTRM alone cannot go further if the FTS requirements are not first identified. There are two sources of requirements: the first one are requirements set by the regulatory framework and the second one are the requirements set by the supply chain. For instance, within supply chain safety requirements the General Food Law article 18 paragraphs 2 to 3 (ECC, 2002), asks to have in place a suppliers identification system; therefore just by identifying the members up and down and ensuring they have procedures in place for internal traceability is enough to comply with the law (one-up-one-down approach). Some supply chains are more entrepreneurial and are working closely with their partners so that safety information can be made available to the supply chain on real-time basis (Verdenius, 2006); therefore saving supply chain transaction costs (Starbird and Amanor-Boadu, 2007), engaging management on the traceability process, increasing customers' trust and decreasing customers' perceived risk (van Rijswijk et al., 2008). Moreover some supply chain partners including regulatory bodies, are creating new information requirements under a co-regulatory setting (Garcia Martinez et al., 2007).

When a FTRM is compared against the required FTS, then it is possible to obtain the resources demanded for economic evaluation of the innovation/upgrade. In order to do that, a framework is proposed for farmers FTS on Table 2 (see Annex I for complete supply chain version). First, the FTRM is constructed including all attributes, entities and/or activities. Then it is customized according to the resources demanded by company and supply chain FTS. A decision on precision is needed for firm level analysis and on external breadth and depth for supply chain analysis in order to arrive to requirements (Annex I). If the requirements are established by law, then the FTRM (Column 1, Table2) would be customized to the law requirements (column 2, Table 2). If the requirements come from private initiative, then the FTRM (Column 1, Table 2) would be customized to company's requirements (Column 3, Table 2). After obtaining the requirements, the switching costs from a legendary system would then be identified according to the resources needed by a FTS (See Annex I).

Table 2. Conceptual FrameworkUsing FTRM for economic evaluation of a farmers' FTS

					Precision
			Food Traceability system Requirements		**Resource allocation on Record-Keeping (traceability) systems (Figure 1)**
		Food traceability reference model (1)	**Practice to comply with General food Law (2)**	**Practice to comply with Supply Chain Strategy (3)**	
Depth 1st Tier	**External Breadth**	***Farmer (entities or attributes to trace)***	***Farmer (entities or attributes requirement)***	***Farmer (entities or attributes requirement)***	**Implementation costs**
		Name, address of customer, nature of products that were delivered to a supply chain customer.	Name, address of customer, nature of products that were delivered to a supply chain customer.	Name, address of customer, nature of products that were delivered to a supply chain customer.	
		Date of transaction / delivery.	Date of transaction / delivery.	Date of transaction / delivery.	
		More detailed description of the product	Pre-packed or bulk product, variety of fruit/vegetable, raw or processed product	Details of the product that want to be shared to obtain a Price premium	
Source: Proposed by the authors based on guidance on implementation of general Food Law (ECC, 2002b)					See complete version on Annex I

There are different costs that would vary after identifying them on the FTRM customization stage (Annex I). More specifically identification and appraisal costs (i.e., cost of tests, audits, inspection, changes in practices, process control measurements, equipment purchase and depreciation and other appraisal and identification costs), transaction cost (i.e., sale cost, suppliers prevention cost, customers prevention costs, external failure cost, liability cost) and overall administration costs. Once costs are estimated; potential benefits of the system innovation can then be considered or modelled. A cost-benefit analysis would determine the net benefits for a supply chain to innovate/upgrade their FTS; allowing economic evaluation drive the FTS design process.

The benefits of using FTRM are that they can help economists identify the requirements and trade offs of alternative traceability systems or specifications there in. It can also help understand and better use other economic evaluation tools such as cost-benefit analysis and/or life cycle analysis. Moreover, it allows economists to use tools developed for information systems design. On the problems side, if used in regulatory impact assessment analysis, there might be a lost in systems diversity (Schiefer, 2004). Moreover, because FTRM are universal, they include several representations and not all of them are used.

5. Conclusion

The present paper proposes a framework for economic evaluation of FTS based on FTRM. Though, the paper focuses on the food industry, the same framework could be applied to other business areas. In order to use FTRM for economic evaluation, requirements (legal and/or customer) must first be identified. The economic evaluation of FTS based on these two different requirements can be done by using FTRM. However, more investigation is needed to clarify the boundaries of the two requirements and their effects on FTS design and their innovation/upgrade.

FTRM focus on the implementation of different FTS in supply chains. Because cost/benefit analysis present several problems as supply chain members will not disclose financial information then alternative method had to be suggested to perform the economic analysis. The framework proposed in this paper uses FTRM to generate economic evaluation. The framework asks to customize the FTRM against FTS requirements of companies and determine the resources needed in four areas: identification, information, procedure and organization. This enables to estimate supply chain costs. Yet the framework has some major drawbacks that have to be further studied, the process of doing evaluation through FTRM requires determining the usefulness of the system a-priori. The process of building FTRM and recognizing all the FTS requirements demand a generous amount of persons per month is data intensive and subjective to the system assumption.

Supply chain traceability systems allow other companies to access certain traceable information; usually the best way to achieve this is to automate the process of data identification placing state of the art sensors that can allow information sharing on almost-real-time and save testing costs. These requirements tend to be expensive; their efficiency against the effectiveness has to be studied. FTRM can guide the process of implementing a FTS and economically evaluating it.

Also, because FTRM are difficult to develop we suggest to work on an unified FTRM database to allow cost evaluators access the blueprints proposed by different FTS. Thus a more clear difference on the traceability requirements would be possible to obtain according the system under consideration.

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