Intra and Inter organisational determinants of adoption of electronic traceability technology: evidence from the French agri-food industry

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Abstract— Traceability, the ability to trace the origin of products throughout the supply chain, has become an instrument to ensure food quality and safety in agri-food chains. This process takes place within a context that is characterized by both institutional and market constraints, yet it also integrates a technological sphere marked by the unprecedented development of information and communication technologies. This paper analyses the factors influencing firms' behaviour, with regards to the adoption of electronic traceability technologies, in the French agri-food industry. We use data from the ICT and E-Commerce survey, carried out in 2002 by the French National Institute of Statistics (INSEE). We use a probit type model, which enables us to take into account the factors that determine the firm's organisational choice, by making a distinction between the firms that adopt electronic traceability technologies and those that do not. Traceability technologies evidence the complementarities between organisational and technological practices as well as the role of their competitive, industrial and local environment. Large industrial firms known for their brand image seem distant from standard traceability practices, contrarily to agribusinesses, which are subjected to regulations and use traceability in order to comply with their downstream contracts and to add value to their regional specificities.

Keywords— Traceability, Technology adoption, Agri-food industry, ICTs, Firm's organisation

I. INTRODUCTION

Traceability, the ability to trace the origin of products throughout the supply chain, has become an instrument to ensure food quality and safety in agri-food chains. Following the BSE crisis in Europe and more recently the E-coli spread through the U.S. spinach supply chain, countries and agribusinesses have been developing traceability systems to ensure food quality and, at the same time, improve supply chain management. By means of regulations, and in particular the European Regulation 178/2002, governments can require agribusinesses to implement mandatory traceability systems in order to improve food safety (Golan et al., 2004). This process takes place within a context characterized by a double constraint: that related to the market and its failures – particularly in the face of consumers' demands – and that related to institutional rules and standardization processes, which have multiplied in recent years. It is also situated within a technological context that is marked by an unprecedented development of ICT (information and communication technologies). Traceability systems require new ICTs that guarantee the recording and transmission of production data all along the supply chain.

In this context, the implications of traceability have given rise to an abundant empirical literature that examines its implementation in specific sectors, and in particular in agribusiness in which questions of food safety are particularly important. Several authors show the diversity within and between sectors and the uncertainty concerning the demand. This diversity in the sector's configuration might have its origins at microeconomic level, in the firms' traceability adoption behaviour (particularly the adoption of an electronic system),

which seems to be an important precondition in order to analyse its consequences on firms and supply chains; a question seldom examined in the literature.

This paper aims to analyse the factors, which, in the French agri-food industry, influence firms' behaviour with regards to traceability. Our goal is to show, on the one hand, the determinants related to firms' characteristics (structure, organisational forms, product differentiation, etc.), and on the other, the factors related to their environment. To what extent does a firm's sectoral, geographical and competitive environment, play a role on its decision to implement traceability? More precisely, our aim is to identify the firm's internal organisational characteristics, the coordination modes, and the environment-related factors that are conducive (or not) to the adoption of an electronic traceability system.

Our theoretical approach derives from innovation theories – which helps us to better understand some of the organisational foundations in the new technology adoption process – and more precisely from recent studies that lie at the intersection of spatial and industrial economics (Battisti and Stoneman, 2005 ; Galliano and Roux, 2008). To test our theoretical model and hypothesis, we use individual data from a national survey (ICT and E-Commerce 2002) conducted by the French Statistic Institutes, which gives us information about the internal and external organisation of the firms, their ICT and traceability capabilities and their relations to the territory. Empirically, we use a probit type model, which enables us to take into account the factors that influence the firms' organisational choices, by distinguishing the firms that adopt an electronic traceability tool from those that do not.

The paper is organised as follows: section 2 examines the theoretical framework of traceability technology and ICT adoption. Section 3 is devoted to the presentation of our data, the probit model and the variables. Section 4 presents the results of the econometric tests performed firstly on the entire French industrial sector, and secondly on the agribusiness industry alone. The last section concludes the paper.

II. ICT, FIRM ORGANISATION AND THE ADOPTION OF TRACEABILITY TECHNOLOGIES: A THEORETICAL FRAMEWORK

A traceability system is bound by two main types of constraints: those related to the market and to market failures, especially with regards to consumers' demands; and those related to institutional rules and norms, which have multiplied considerably in recent years (Ménard and Valceschini, 2005). They are also within a technological framework influenced by the development of new ICT. Traceability systems require ICTs, which are necessary for the registration, transfer and stock of information and knowledge. As noted by Buhr (2003), ICT

and information systems have made it economically feasible to develop logistic management and monitoring, enabling the traceability of food products through the labyrinth of the agri-food supply chain.

Nonetheless not all firms have adopted an electronic traceability system[1] and the technologies used for this purpose and the degree of intensity with which these technologies are used vary from firm to firm. What then, are the factors, which, at microeconomic level, favour or do not favour the adoption of an electronic traceability system? After describing our theoretical framework – inspired by technology adoption models (Battisti and Stoneman, 2005; Galliano and Roux, 2008) – we shall present the determinants of adoption of electronic traceability systems. The idea is to highlight three main sets of variables: those related to firms' organisational structure, those related to its environment and those related to the types of technology that already exist in the firm.

A. The theoretical framework of electronic traceability adoption: The adoption models

The literature on technology adoption proposes different models to explain the diffusion of technologies: the equilibrium models, whereby the decision to adopt is based on a cost-benefit analysis; and the epidemic models, which take into account the effects of information spill-overs on the diffusion of technologies (see Karshenas and Stoneman, 1993). Thus, in the *cost-benefit approach of equilibrium models*, the decision to adopt is the result of an economic calculation by potential adopters (firms), who anticipate the net costs and benefits of adopting and using these technologies. These models are based on the hypothesis that information about the technology is known and shared, and that the difference in the adoption levels between actors is a product of their heterogeneity. The expected benefits from the technology will depend on the firms' own characteristics ('rank effects') and on their position in the adoption order ('stock and order effects'). Rank effects suggest that firms differ in their own characteristics. Firms differ in characteristics such as size, financial resources, market position, etc. They do not have the same needs and expectation *vis-à-vis* the technology. In addition, as noted by several authors, the choices and the adoption model, as well as the performance of the technology, will depend on the compatibility of the latter with the firm's goals and its coherence with the organisational structures (Milgrom et Roberts, 1995). The decision to adopt ICT or traceability technologies requires complementary organisational innovations by firms (Greenan, 2003; Bocquet et al. 2007).

Epidemic models emphasize the predominance of information spillover effects on the diffusion of technologies. The greater the number of adopters, the more information is

[1] It has been mentioned that most traceability systems remain partially supported on paper forms (FoodTrace, 2004)

available about the technologies and the faster the diffusion rate. These models hypothesize that a potential user becomes a user through contact with an existing adopter (the greater the number of adopters, the higher the probability of a non-adopter to be in contact with an adopter and the higher his probability of being 'contaminated').

Integrating these two approaches on technology diffusion, authors obtain technology adoption models that take into account the rank effects related to the firm's characteristics, the stock and order effects in the case of inter-firm diffusion and the epidemic effects[2]. Using Galliano and Roux's model (2008) on ICT adoption, and Battisti and Stoneman's work (2005), we can describe the process of technology adoption, or that of electronic traceability adoption, by considering a binary discrete variable d_i^t that takes value 1 if the firm possesses the new technology at time *t*, and 0 otherwise. At time *t*, a firm possesses the new technology if and only if the net profit it has anticipated from its adoption in relation to its non-adoption is positive.

The expected net profit of adoption noted $\theta(x_i^t)$ is a function of the firm's specific characteristics as well as those of its sectoral, competitive, and geographical environments (rank effects). The firm's own characteristics correspond not only to its structure (size) but also to its organisation (multi-unit firms, subsidiary of a group, degree of product specificities, management information system (MIS), degree of codification practices, etc). These variables allow us, in the diffusion model of traceability related technologies, to take into account the complementarities between organisational and technological practices. We now make the additional hypothesis that spillover effects (geographic and sector related) influence the firm's decision to adopt the new technology. Indeed, the adoption of a new technology by other firms in the same sector, or geographical area, generates information spillovers that may lead the firm to adopt this technology in so far as these spillovers reduce the uncertainty concerning its characteristics. These epidemic effects are denoted e_i^t. We consider that a firm *i* possesses the new technology at time *t*, i.e. $d_i^{n,t} = 1$, if the subjective expected net profit (in relation to non-adoption) is positive:

$$\pi(x_i^t, e_i^t) = \theta(x_i^t) + f(e_i^t) > 0 \quad (1)$$

[2] In the absence of the adoption date, we are unable to calculate the position of the firms in the adoption order and so we cannot estimate the stock and order effects.

The first term represents the net profits anticipated by the firm while the second term represents a correction in this perception that information spillovers have an effect on the firm's technological characteristics.

B. The explanatory factors of adoption of traceability technology

The goal of this section is to describe the different factors that influence a firm's decision to adopt an electronic traceability system. The theoretical adoption models show two types of factors: rank effects and epidemic effects. Rank effects are those related to the firm's internal characteristics and external coordination modes. They reaffirm the complementary effects between, on the one hand, technological and organisational practices, and on the other, the firm's management, represented by its MIS technologies, which are determinants of the firm's codification practices. Thus, the first three sub-sections are dedicated to the rank effects (internal characteristics and those of the environment), and to the organisational practices respectively. In this third sub-section of our study on traceability, we shall try and determine the practices of information management and of communication adopted by the firms through their use of technologies. The fourth, and last sub-section, will be dedicated to the epidemic effects.

i. The firm's internal organisational characteristics:

We make the hypothesis that each firm has internal characteristics that influence its needs and capacities to adopt a new technology. Rank effects related to the firm's internal characteristics show that not only size but also internal and external coordination modes play role in the process of adoption of a traceability technology.

The size of the firm: Firms have different characteristics that influence their adoption behaviour. Among these, *the firm's size* is expected to have an effect on the adoption process. Large firms are described as having greater access to financial resources, benefiting from economies of scale, having a relatively diverse workforce in terms of skills and having better access to information on new technologies. They also have greater negotiating power when dealing with suppliers. Some authors believe that size of the firms determines the resources allocated to traceability activities (Rabade and Alfaro, 2006). If we consider electronic traceability as an ICT, the literature shows vast evidence on the role of the firm's size and the adoption of new technologies (Mansfield, 1968; Karshenas and Stoneman, 1993; Galliano and Roux, 2006). Though this relation is not always linear, the adoption of traceability systems depends, overall, on the size and complexity of the firms.

Internal and external organization: Traceability involves the coordination of different operators (Souza-Monteiro and Caswell, 2005; Charlier and Valceschini, 2008). Information technologies are tools used to facilitate communication and coordination at both intra and inter-firm levels: the higher the monitoring and coordination costs, the higher the expected returns from using ICT. This seems to be particularly true in the agri-food sector where traceability, especially when supported by information technologies, tend to reduce such costs (Buhr, 2003). Besides the size of the firm, the literature identifies other factors, related to the firm's structure that could have an influence on the adoption of certain technologies like for example *a multi-unit organisational form*. The multi-location of production units across different locations means higher costs of communication and coordination between them. Various empirical works corroborate that multi-unit firms (MUF) play a positive role in the adoption of ICT (Fischer and Johansson, 1994, Galliano and Roux, 2008). This might not be the case with food safety measures. Bouhsina et al. (2002) found that the number of units within a firm is negatively correlated to the probability of adopting a generic food quality standard (ISO 9000 and HACCP).

Product differentiation: It is widely emphasized in the literature that one of the main reasons for implementing a traceability system is to reassure consumers about quality and safety of the products they produce. It is believed that the costs of new products are high because of the marketing expenditures and that advertising is the most widely used tool to inform consumers about food quality and safety (Verbeke, 2005). *The firm's rate of advertising expenditures* can be indicative of the importance the firm attaches to its brand image and product differentiation which helps us to understand the role these factors play in the process of adoption of traceability technologies. It could be used as a tool to efficiently measure the 'differentiation' among firms that use their image to promote their products. Advertising and traceability can be complementary or interchangeable in building the consumers' trust. Verbeke (2005) suggests that traceability itself is not the most important factor in increasing consumer trust. However, when it is mentioned in quality labels it stands a good chance of being valued by consumers. Based on this relation between advertisement and traceability, our goal is to determine whether firms that employ a large amount of resources in advertising have a greater probability of adopting electronic traceability systems.

ii. The factors related to firms' environment: location area, sector of activity and market structure:

Location area: The general view is that firms are influenced by the environment in which they are located, especially in their capacity to innovate and to adopt new technologies. The

hypothesis, often found in the literature, is that urban agglomeration economies facilitate access to a variety of infrastructures and service activities (IT services, technology suppliers etc.), as well as to a qualified workforce, which favours the adoption of technologies by firms. The relative scarcity of these factors in rural areas, together with a low technological level, could explain the delay in the adoption process of rural firms (Gale, 1998). At the same time, according to Antonelli (1999), the level of industrial specialisation in the area where the firm is located also plays a role because it creates a dense network of relationships between firms (suppliers, associated services etc.), which generates a need for traceability and, favours the diffusion of information and technologies. Rabade and Alfaro (2006) show that the geographical location of suppliers determines the degree of coordination between buyers and suppliers, which in turn conditions the strength of the collaborative relationships.

The firm's sector of activity: The influence of the firm's sector of activity on its adoption behaviour can be related, first, to the technical characteristics of the industry, as well as the firm's downstream and upstream relationships, and to the regulations existing in the sector. The first aspect concerns the nature of the product and the modes of organisation between the supply chain operators. Information is more or less standardized and codified depending on the type of product, and the type of coordination. The pressure from distributors (downstream) remains an important determinant in the choice of a traceability system. At the same time, agribusinesses are strongly influenced by laws and regulations concerning food safety. Liability costs are also important determinants in the firm's decision to implement or upgrade a traceability system (Hobbs, 2004). Agribusiness is a sector that is particularly exposed to the multiplication of coordination and product standardization mechanisms, and of production modes that involve all actors from farmers to consumers.

Market determinants: Though downstream pressure is a significant sectoral effect, at the level of supply chains, the market structure and competition can also play a role in the firm's decision to adopt new technologies and an efficient traceability system. The theoretical literature tends to show that a firm's innovation capacity and its pace of innovation depend on its position on the market (Reinganum, 1989). The effects of competitive pressure on the firm's innovation capacity somehow remain unclear in the literature; we assert that a highly competitive environment could be an incentive for firms to innovate in order to defend its market share.

iii. The types of tools:

The type of tools used by a firm is an indicator of its organisation management choice, especially the degree of formalisation and codification of practices and knowledge. These

tolls indicate the nature of the information system used in the firm, and on which the electronic traceability systems is or will be based.

These technologies should structure both the firm's internal and external flow of traceability information. Different authors (Van der Vorst et al., 2005; Faraggi, 2006) have identified three main functions of traceability technologies within a firm: i) Identification and registration of lots; ii) Management of traceability data; and iii) communication of traceability data. Technologies used for the *identification and registration of lots* can range from the well known bar-coded tag to the more sophisticated RFID (Radio Frequency Identification Devices), ear tags and DNA-tracing (see Briz, 2003). Some of the technologies used for the *management of traceability data* that can be found in industrial and agri-food firms are typically ERP (Enterprise Resource Planning System) and WMS (Warehouse Management Systems). For the *communication of traceability data*, the tendency is to use standard electronic formats such as EDI (Electronic Data Interchange), yet Intranet and Extranet are widely used. In the process of traceability, the management and communication tools in some way condition the process of traceability codification at a time *t*. Our hypothesis is that the presence of management and communication tools favours the implementation of an electronic traceability system in the firm.

iv. Epidemic effects related to uncertainty about the technology (sectoral and spatial effects):

Epidemic modelling emphasizes the predominance of information spill-overs on the adoption of technologies. The pace and extent of their diffusion will depend on the number of adopters in the firm's environment. The more a new technology is used, the more information is transferred between and within firms, and the lower the risk associated with its adoption. This effect could be analysed at the sectoral and spatial levels. We shall analyze the influence played by the traceaility technology users that belong to the same sector as the observed firm and that played by those located in the same geographical area. Is the probability of adopting a traceability system dependent on a sectoral or a spatial effect related to the firm's environment? This question is rarely considered in the literature.

III. DATA AND METHODS

A. The data

We have used data from the *ICT and E-commerce Survey*, carried out in 2002 by the French National Institute of Statistics (INSEE-SESSI-SCEES). This survey gives us information

about the existence of traceability and other ICT tools, as well as their practical usages by French firms. We have combined this data with that of the Firms Annual Survey (EAE), also conducted by INSEE.

The EAE survey provides us with exhaustive information on the firms' activities, structural characteristics, number of units, and location of their main office. The survey is based on a representative sample - in size and sector of activity - of over 5000 French industrial firms, which in weighted data represent over 22000 firms. The Financial Links (LIFI) Survey gives information about whether the firms belong to a group or not. Finally, we use data from the ZAUER zoning database (INSEE-INRA, 1998), which provides information about the nature of the firms' geographical location (urban or rural area). The obtained typology allows for the categorisation of all French cities (or "*communes*") into seven spatial categories that we have aggregated into 4 levels: urban zones, peri-urban zones, rural poles, and rural isolated zones. Table 1 provides some descriptive statistics on our sample.

The descriptive statistics show the important role played by the firm's structural and organisational characteristics in the adoption of electronic traceability technology (size, group organisation, etc.) They also show the specificities of agribusiness compared with the rest of the French production system. Agribusiness seems to be the industrial sector that uses electronic traceability technologies the most.

[Insert Table 1]

B. Methodology

Based on data from these individual firms, we use a probit-type model, which enables us to take into account the factors that determine the firms' organisational choices, by distinguishing the firms that adopt a traceability tool from those that do not. Beyond merely providing an exhaustive statistical description of traceability in the agribusiness sector, our main objective is to test, using an econometric model, the factors that influence firms' decisions to use electronic traceability systems. For all estimations we use weighted data, in order to correct for sampling bias (i.e. for ensuring a better representation of the individual firm's distribution) and provide results for the entire population. Probit models are used to explain a dichotomous dependent variable with empirical specifications in terms of a latent regression (Greene, 2003):

$$y_i = \beta x_i + \varepsilon_i$$

Where x_i is a vector of endogenous variables, β the vector of parameters and ε_i, the residual error, which is normally distributed. The latent variable y_i is continuous and unobserved, and generates the observed binary variable y_i where:

$$y_i = 1 \text{ if } y > 0 \quad \text{and} \quad y_i = 0 \text{ if } y \leq 0$$

C. Variables

This section presents the nature of the different variables used in the model, that is, firstly the explained variable, and secondly the explanatory variables. These explanatory variables are divided into three categories: the internal characteristics of the firm, the characteristics of the environment and, finally, the type of tools used.

Explained variable: We estimate the probability of adopting an electronic traceability tool. We use a dichotomous variable taking value 1 if the firm has adopted a traceability tool and 0 otherwise. We use the *traceability tool* variable – derived from the 2002 ICT and Electronic Commerce survey – described in the survey's questionnaire as a "tool that makes it possible to determine, in real time, the origin, location and history of a product", and which is dependent upon "information technology mechanisms, such as bar codes, electronic tags, etc. and other type of product identification technologies".

Explanatory variables related to the firm's internal characteristics: Several variables found in the literature are used to describe firms' internal characteristics. Firstly, the *size of the firm* is estimated by the number of employees. Firms are divided into four categories according to the number of workers they employ (from 20 to 50; from 50 to 100; from 100 to 500, and over 500 employees). The *belonging to a group* variable indicates that firms are integrated to a larger network and so have a higher probability of adopting ICT and traceability systems, even if this integration depends on the functional division and the level of decision making centralization within the group. The spatial organisation of the firm is determined by a *multi-unit* (or single unit) *structure*. While the product differentiation is measured by its *advertisement ratio*, the proportion of advertisement expenses over total revenues.

Explanatory variables related to the firm's external environment: This set of variables is used in order to describe the environment of firms in their different dimensions: sectoral, spatial and market related. The main *sector of activity* of the firm – at the level 60 of the NAF[3] – reveals the technological and economical determinants related to the firm's sector. With regards to the spatial environment, we use the *location of the head office*, according to

[3] French Nomenclature of Activity. For agribusiness we use the sectors at the 220 NAF's level, which composes: meat, fishery, fruits and vegetables, oilseeds, milk, grains and starch, animal feed, other food industries and beverages.

the INSEE-INRA's ZAUER zoning, to distinguish three types of locations: urban centres, peri-urban, rural poles and rural isolated areas (INSEE-INRA 1998).

With respect to the market environment, we use – for the *level of competition in the sector* – the logarithm of the C4 concentration indicator, calculated from the market shares (cumulated) of the top four firms on the market[4]. This indicator is used to test the hypothesis according to which the firm's search for market power is a determinant of its adoption behaviour. Secondly we use the firm's rate of exports, which reflects the firm's *degree of openness to foreign markets*. The aim here is to evaluate how much the presence of a firm on foreign markets influences its traceability adoption behaviour.

Two types of epidemic effects are studied: spatial and sector related effects. For the former we use the *level of firms' traceability adoption in the local geographic area*, meaning the average rate of use of traceability technology by the firms located in the same "*département*"[5], and for the former, we use the *level of traceability adoption in the firm's sector*, that is, the average rate of use of traceability tool in the firm's sector of activity.

The explanatory variables that characterize the firm's ICT system: In order to outline the firm's information system, we try to identify the relation between a firm's information management and communication tools and its traceability technology adoption behaviour. Thanks to the ICT survey we can take into consideration the existence of information management tools (ERP, DMS, Workflow and Datawarehouse) in the firm and its modes of communication whether they are internally or externally oriented (EDI, Intranet, Extranet).

IV. RESULTS: THE DETERMINANTS OF ADOPTION OF ELECTRONIC TRACEABILITY TOOLS – THE SPECIFICITIES OF AGRI-FOOD IN THE FRENCH INDUSTRY

The results of the econometric model – concerning the whole sample of French industrial firms – show the influence of both internal and external factors on the firm's adoption behaviour (table 2). They show the role played by organisational factors and those related to the firm's external environment. In this regard, the general model shows the specific and highly significant role of traceability in the agri-food industry. Firms in the agri-food sector have a higher probability of adopting an electronic traceability tool than those in the intermediate goods, consumer goods, equipment goods and automobile sectors. This highly significant and positive result tends to confirm the specific importance of traceability in

[4] Log of C4, at the 220 level of the French sector's nomenclature.
[5] French administrative unit situated in between *regions* and *counties*.

agribusinesses and the relevance of further examining and comparing the behaviour of agribusiness with that of firms in other industrial sectors.

A. Firm's internal characteristics

Concerning the organisational characteristics of firms, even though the general model shows the overall relevance of the firm's size and the fact that it belongs to a group, there are some marked differences between sectors in terms of their adoption probability. Among industrial firms (outside the agribusiness sector), the probability of adoption increases for firms employing between 20 and 500 people. This is not the case for firms that employ more than 500 employees. The size of large firms does not play a significant role on the adoption behaviour, which explains the negative role played by the firm's multi-unit structure. This is also reinforced by the negative and significant role played by the advertisement expenditures; a measure of the firm's branding strategy (a practice characteristic of large enterprises). The industrial model becomes that of the average firm, i.e. a firm that manufactures standard products and is characterized by vertical relationships, typical of the sector or group it belongs to.

In the agri-food industry, the probability of adopting an electronic traceability system is correlated to the increase in the firm's size. Large firms have a greater probability of implementing electronic traceability systems, this supports the fact that a large number of SMEs relay on paper-based traceability.

Moreover, belonging to a group increases a firm's probability of adopting an electronic traceability tool. Whether the firm has a single or a multi-unit form of organisation is not significant in the adoption process. The fact that firms possess multiple units – which in agribusiness is often considered as a way of taking advantage of both urban and rural externalities (Galliano and Roux, 2006) – does not play a role in the adoption behaviour. However, in contrast to the rest of the industry, the rate of advertising expenditures – which provides an indication of the importance attached to the brand image development strategy – has a positive and non-significant effect. Traceability tends to be as formalized and developed in the case of generic products or products belonging to vertical integrated supply chains (B-to-B process) as it is in the case of brand products. This aspect can better be developed with voluntary labels like AOC, PDO, PGI, etc., which do not depend on firms' size.

[Insert table 2]

B. The environmental factors

With regards to the firm's environment, the overall results tend to show that the spatial environment has a more nuanced effect than the sectoral or market related environment. As far as the spatial environment is concerned, the process of traceability adoption is favoured in the case of industrial firms (excl. agribusiness) located in urban and peri-urban areas. The probability of adopting traceability tools is higher and more significant for peri-urban firms than for firms located in other types of areas. Being located in a rural isolated area, plays a negative role in the probability of adopting electronic traceability tools and this applies to all firms in the sample. This result is in keeping with those in the literature about the adoption of innovations and new technologies, whereby the urban externalities are the ones influencing innovation.

In the case of the agri-food industry, the model is different because agribusinesses are typically located in rural areas, and are strongly influenced by the spatial externalities related to the location of their head offices. Thus being located in a rural pole, and to a lesser degree, in a peri-urban area, is more favourable to adoption than being located in an urban pole. On the other hand, being located in an isolated rural area has a negative influence on the decision to adopt traceability tools. This result seems to be related to the low level of technological intensity of the products manufactured in rural areas and therefore of the skills needed to produce them (Gale, 1998), and to the influence of information spillovers on innovation.

The market environment plays different roles depending on the sector of activity. If the export rate, and so the openness to international markets, have a positive effect for all firms, we found that the level of competition on the firms' market does not play a significant role in the case of industrial firms. However, it plays a highly positive and significant role in the case of agribusiness. This tends to confirm the influence of vertical integration and sector-related effects on their traceability behaviour. These results are reinforced by the epidemic effects, which only play a significant role from a sector-related point of view. The fact that other firms in the same geographical are use traceability technologies does not have a significant influence on the firm's probability of adoption them.

Results show several differences between the various agri-food sub-sectors. The empirical literature tends to show that sectors affected by the various sanitary crisis and food safety issues had a higher probability of implementing traceability systems even before regulations were implemented in the late 90's. Nevertheless, as the results of our model show, the implementation of an electronic traceability system implies the existence different factors and positive externalities – such as the size or the environment – favourable to the adoption of these tools. The meat industry is less concentrated; firms in this sector are medium sized

(slaughter-houses) and are often located in rural areas. The integration level in the supply chain and the pressure from downstream operators play a distinct role in the type of tools used and the degree of traceability implemented. The model shows how sectors like the dairy and the fruit and vegetable industries behave similarly to the met sector. However, firms in the fishing and the animal feed industries remain industrialized and have a higher probability of adoption an electronic traceability system than those in the meat industry do. In the vegetable and the crop sectors, health related requirements have a lesser influence on the decision to implement traceability systems; yet pressure from downstream operators has a higher influence. Compared with the meat industry, the beverage sector has a much higher and more significant probability of adoption electronic traceability technologies. This sector has historically been highly regulated – because of the alcohol contained in some products – yet it is also subjected to strong competition and product differentiation.

C. The type of tools

Finally, the management and transmission of traceability data along the supply chain between upstream and downstream partners require, require, first of all, a series of complementary tools that can capture and process the data (enterprise resource planning ERP, supply chain management software, etc.) and second of all, tools facilitating the transmission of data (Extranet, EDI, Intranet, etc.). As we have seen (table 1) the most used traceability information processing tool is ERP (66,48% of adopters), while the most used transmission tool is EDI (64,06%). Nevertheless, these tools are also more or less used by firms that have not adopted traceability technologies, while DMS and Workflow seem to be more specifically oriented toward traceability. In terms of communication technologies, we have found that Intranet and EDI are the traceability tools that industrial and agribusiness firms use the most (EDI in particular is widely used in agribusiness). Thus, regardless of the sector, the presence of these communication and complementary tools, representing organisational practices and specific informational structures, significantly increases the probability of adopting an electronic traceability system. A traceability tool, besides being an ICT for the transmission of a firm's product data is also a complex and systemic organisational practice that affects the internal and external organisation of the firm.

V. CONCLUSION

Our goal in this paper has been to analyse the microeconomic determinants of agribusinesses' decision to adopt electronic traceability systems and to explain what

distinguishes the agribusiness sector from other industrial sectors. Our theoretical approaches derive from innovation theories which help us to understand some of the organisational roots of the process of adoption of the new technologies, and more precisely the influence of firms' characteristics and environmental factors respectively.

Our empirical model shows that a firm's choices (the decision to adopt electronic traceability tools) depend on and interact with the firm's own organisational characteristics and those of its competitive, industrial and local environment. For agribusinesses, results tend to show that the spatial, sector-related and commercial environments play a central role. The internal organisational factors, beyond size and belonging to a group do not play a major role in the traceability behaviour. This contrasts with industrial firms, which are more focused on their internal needs and less exposed to environmental effects. Large industrial firms with an established brand name and brand image are not yet part of the standard process of traceability, in this respect they contrast sharply with agribusiness, which are subjected to strict regulations, use traceability technology so as to be able to comply with contractual demands from downstream and develop an make the most of their specificity, particularly that related to their territory. The fact that advertising has more or less influence depending on the type of firm shows the potential benefits of analysing the interactions between organisational dynamics and the institutional, commercial and technological constraints affecting the firms. These results call for further research on the interactions between firms' information systems and traceability systems, specifically on the complementarities between technical innovations and organisational innovations.

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TABLES

Table 1 The characteristics of adopting firms

		The whole industrial sector	The whole industrial sector (excl. Agri-food)	Agri-food	
Total num. of firms		22 965	20 115		2 856
Num. of adopters		5 355	4 134		1 222
In percentage (%)		23,31	20,55		42,78
Size	20 to 49 emplo.	60,43	61,10		58,10
	50 to 99	16,51	16,22		16,12
	100 to 499	13,69	12,85		16,45
	500 or more	9,34	9,36		9,25
Sector	Agri-food	22,81	-	Meat indust.	38,79
	Consumer goods	13,79	-	Fishery	5,56
	Automobile	2,28	-	Fruits & Veg.	4,58
	Equipment goods	13,39	-	Oilseeds	0,41
	Interme. goods	47,74	-	Milk	10,56
				Grains & starch	3,60
				Feed	6,63
				Other food ind.	19,39
				Beverages	10,31
Organisational form	Subsidiary	71,00	70,66		72,10
	Independent	29,00	29,33		27,86
	Single Unit	62,66	64,48		56,47
	Multi Unit	37,34	35,52		43,50
Spatial organisation	Urban area	58,68	62,41		46,00
	Peri-Urban area	20,74	20,25		22,43
	Rural pole	10,15	07,81		18,03
	Rural isolated	10,42	09,51		13,50
Data manage. tools	ERP	66,48	69,11		57,60
	DMS	23,51	25,06		18,23
	Workflow	22,79	24,58		16,74
	Datawarehouse-Datamining	24,79	25,25		23,24
Com. tools	EDI	64,06	60,91		74,62
	Intranet	54,39	55,32		51,20
	Extranet	18,11	19,96		11,83

Source:EAE and ICT and E-Commerce Survey (2002), French National Institutes of statistics, Authors' calculation

Table 2 The determinants of the firm's traceability adoption

			Endogenous variable:		Traceability adoption
		Total (model 1)	Industries (model 2)	Agri-food (model 3)	
I. Internal characteristics of the firm					
Size	20<50	(Ref)	(Ref)		(Ref)
	50<100	0.136 ***	0.121 ***		0.280 ***
	100<500	0.218 ***	0.159 ***		0.534 ***
	>500	0.152 ***	0.089 ns		0.419 ***
Belonging to a group		0.171 ***	0.164 ***		0.220 ***
Multi-unit spatial organization		- 0.082 ***	- 0.080 ***		-0.010 ns
Advertising ratio		- 0.618 ns	- 2.551 ***		0.360 ns
II. Characteristics of the environment					
Firms' environment-related factors					
Head office's location	- Urban	(Ref)	(Ref)		(Ref)
	- Peri-urban	0.116 ***	0.103 ***		0.194 **
	- Rural pole	0.025 ns	- 0.077 **		0.423 ***
	- Rural isolated	-0.129 ***	- 0.098 ***		-0.188 **
Sector	Agri-food	(Ref)	-	Meat industry	(Ref.)
	Consumption goods	-0.711 ***	(Ref)	Fishery	0.521 **
	Automobile	-0.675 ***	0.018 ns	Fruits and vegetab.	0.177 ns
	Equipment goods	-0.760 ***	-0.070 **	Oilseeds	-0.348 ns
	Intermediary goods	-0.390 ***	-0.293 ***	Milk	0.093 ns
				Grains and starch	0.470 *
				Feed	0.532 ***
				Other food indust.	0.144 ns
				Beverages	0.452 **
Level of competition in the sector		- 0.062 ***	- 0.049 ***		0.375 ***
Rate of openness to international markets		0.199 *	0.219 ***		0.411 *
Epidemic effects					
Level of traceability adoption in the area		-0.001 ns	-0.001 ns		-0.002 ns
Level of traceability adoption in the sector		0.003 ***	0.003 ***		0.026 ***
III Type of tools					
Data Management Tools :	ERP	0.290 ***	0.294 ***		0.206 ***
	DMS	0.349 ***	0.346 ***		0.358 ***
	Workflow	0.512 ***	0.537 ***		0.358 ***
	Datawarehouse	0.311 ***	0.332 ***		0.265 ***
Communication tools :	EDI	0.264 ***	0.264 ***		0.286 ***
	Intranet	0.290 ***	0.266 ***		0.190 ***
	Extranet	0.177 **	0.179 ***		0.164 **
Constant		-1.226***	-1.872***		-1.563***
Number of observations		22 963	20 109		2 853
R2		0.175	0.158		0.182

Source:EAE and ICT and E-Commerce Survey (2002), French National Institutes of statistics, Authors' calculation