Traceability and risks: an extended transaction cost perspective

Abstract

Purpose - The aim of the paper is to investigate the determinants leading firms to choose among different voluntary standards within food supply chains. In specific, we explored the role of transaction risks, i.e. internal and exogenous risks, in the adoption of different traceability schemes.
Design/methodology/approach - A survey was conducted within the Italian population of 216 food-processing firms that adopt voluntary traceability schemes. The identification of different transaction risks was based on the literature on supply chain management and transaction cost economics. An ordinal regression model was used in the analysis.
Findings - Empirical results highlight that the transaction risks perceived by food firms play a significant role on the kind of traceability schemes to adopt. There is a positive link between internal risks and the decision to implement complex schemes. Moreover, a negative relationship between the perceived exogenous risks and the complexity of the standard adopted is also observed. Exogenous transaction risk lead to the implementation of standards which do not imply strong co-ordination. On the contrary, internal risks imply complex schemes that lead to closer supply chain relationships
Research limitations/implications – The analysis is limited to cross-sectional data for a single country and further investigation would help assess the generalizability of the findings.
Practical implications - The analysis can be considered a useful framework to orient firms strategic decisions towards the most appropriate voluntary standard to adopt for an efficient management of vertical relationships within food supply chains.
Originality/value - The present analysis is the first attempt to explain the determinants leading firms to choose among different kinds of voluntary standards within food supply chains. The approach used reveal that transaction risks can be considered a useful framework to explain firms strategic decisions related to the kind of schemes to adopt.

Keywords. voluntary standards, traceability, transaction risks, Transaction Cost economics, ordinal regression analysis

JEL codes. L14, Q13, Q18

1. Introduction

The management of risks surrounding inter-firm relationships has become a central issue for the resilience of supply chains (Ringsberg, 2014). While facing a growing number of risks during exchanges, firms must simultaneously look for adequate forms of transaction governance in order to efficiently manage and reduce such risks.

Transaction cost economics (TCE) is among the most powerful theories used to explain the ways in which economic agents minimise transaction risks and related costs through the governance of vertical relationships. Such a theoretical approach mainly refers to the transaction risks associated with the bounded rationality and opportunism of economic agents (Williamson, 1985; 1991). However, recent literature advances have focused attention on other sources of firm risks (Narsimhalu *et al.*, 2015; Droge *et al.*, 2012; Olmos, 2010; Geyskens *et al.*, 2006; Schilling and

Steensma, 2002; Das and Teng, 2001). These risks are related to changes in the economic environment independently from firms' economic behaviour. Such new forms of uncertainties can have significant economic consequences on the supply chain organisation. The coexistence of different kinds of risks opens new questions regarding the strategic management of vertical relationships.

Food supply chains present a good field of study to explore different forms of transaction risks owing to the specificities that characterise food production. Besides the risks arising from the opportunistic behaviour of economic agents, many other risks related to unexpected changes in the economic environment are present (Henson and Humphrey, 2010). For example, these include the dependence of agricultural raw materials on climatic conditions; frequent safety incidents affecting food activities; rapid changes in consumer preferences; the constant evolution of the food legal framework; and the globalisation of food supply chains. These represent significant challenges affecting vertical relationships and their organisation.

Standards, which are strategic tools to manage risks within food supply chains, are considered as endogenous solutions to problems related to information asymmetries concerning the quality characteristics of food products (Pant *et al.*, 2015; Manzini and Accorsi, 2013). Moreover, they are also considered as effective instruments to tackle unfair practices, like fraud and food adulteration, and to prevent food safety incidents (Manning and Soon, 2014; Peake *et al.*, 2014; Pozo and Schroeder, 2016; Tähkäpää *et al.*, 2015). Food standards influence the management of vertical relationships by the introduction of rules, which increase the transparency of vertical relationships. A growing body of literature considers food standards as institutions that can lead to a reorganisation of vertical relationships through, for example, the centralisation of economic activities or better liability distribution among supply chain agents (Banterle and Stranieri, 2008; Hobbs, 2006; 2004).

The effectiveness of the contribution of food standards to the organisation of vertical relationships and management of transaction risks will depend on the type of standards implemented (Dabbene *et al.*, 2014; Trienekens *et al.*, 2012). Indeed, in the food sector it is possible to reveal the presence of a growing number of voluntary standards, both public and private, characterised either by complex schemes or flexible procedures. (Asioli *et al.*, 2014). Complex standards refer to schemes that imply an increase in information leading to certification, the involvement of a considerable number of supply chain economic agents, and investments in systems able to guarantee the truthfulness of the standards' requirements. By contrast, flexible standards refer to certification of little additional information, the involvement of few economic agents of the supply chain, and the implementation of simple systems.

The proliferation of standards and their different consequences in terms of vertical coordination and risk management raise questions about the determinants leading firms to choose among different kinds of rules and procedures for their implementation. In food economics literature, several studies have focused on the incentives for safety and quality standards adoption (Karlsen *et al.*, 2013).

The aim of this paper is to investigate the role of transaction risks in affecting firm choices between different traceability standards within food supply chains (i.e. between complex and simple standard rules). Specifically, we refer to TCE and to a growing field of literature that considers transaction governance not only as an instrument to reduce transaction costs, but also as a tool to manage different transaction risks (Billitteri *et al.*, 2013; Wever *et al.*, 2012; Geyskens *et al.*, 2006; Miller and Folta, 2002). The risks perceived in vertical relationships – such as, for example, those related to an ineffective management of opportunistic behaviour between transacting parties (internal risks), or the risks associated with unexpected changes in the economic environment (exogenous risks) – can help to explain the choice of different standards.

In our analysis, we focus on voluntary traceability standards. The motivation behind this choice centres on the possibility of economic agents to choose among different kinds of traceability schemes for the implementation of such standards; that is, both flexible and complex traceability rules (Charlebois *et al.*, 2014; Aung and Chang, 2014; Schroeder and Tonsor, 2012). Thus, voluntary standards allow the capture of different levels of supply chain reorganisation. A survey was conducted through a questionnaire with closed answers on an Italian population of 216 food-processing firms that adopt a voluntary traceability scheme. An ordinal regression model was used in the analysis.

The paper is organised as follows: the economics of traceability and the conceptual framework with hypotheses are presented in sections 2 and 3; the methodology is examined in section 4; results are analysed in section 5; and concluding remarks are set down in section 6.

2. Economic issues in food traceability standards

2.1. Definitions

Different definitions of traceability are currently adopted in the food sector. The International Organization for Standardization (ISO) defines traceability as the 'ability to trace the history, application or location of an entity by means of recorded identifications' (ISO, 1994). According to the EU General Food Law (Regulation 178/02, 2002) it is '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'. This is echoed by ISO 22005

(2007), which defines traceability as the 'ability to follow the movement of a feed or food through specified stage(s) of production, processing, and distribution'.

In the scientific literature, there is intense debate on the definition of traceability (Karlsen *et al.*, 2013). Opara and Mazaud (2001) describe it as 'the collection, documentation, maintenance, and application of information related to all processes in the supply chain in a manner that provides a guarantee to the consumer on the origin and life history of a product'. Tavernier (2004) describes traceability as a process that requires the documentation of information within the supply chain; while for Bollen *et al.* (2006), it is 'the means by which the information is provided'. From these definitions, it is possible to synthesise a couple of key features associated with the concept of traceability. First, the aim of traceability is to record information flows within supply chains; and second, traceability refers to the systems that allow firms to record information, so to reconstruct the history of their products.

2.2. EU traceability standards

Current regulation provides a wide range of traceability standards, both mandatory and voluntary (Aung and Chang, 2014). At the EU level, traceability has become mandatory for all food products through Regulation 178/2002. Moreover, Regulation 1760/2000 and Regulation 1825/2000 introduced a specific traceability standard for bovine meat, which has recently been extended (by Regulation 1337/2013) to cover most meat products – including fresh, chilled and frozen meat from pigs, sheep, goats and poultry.

Besides these mandatory rules, additional voluntary traceability standards can also be implemented by food firms to prevent or manage different safety and quality risks at the supply chain level (Dabbene *et al.*, 2014). An inventory compiled for the European Commission (2010) revealed the presence of more than 140 different voluntary traceability standards. These standards can be set down by non-governmental organisations, sector organisations, or individual firms (Chen *et al.*, 2015; Gawron and Theuvsen, 2010). International standards are issued by non-governmental organisations, whereas sector organisations and individual firm standards belong to private initiatives (Hall, 2010).

Among international standards, ISO 22005 can be implemented by food firms to complete or enhance the traceability requirements of the European legislation (ISO, 2007). ISO 22005 requires that each firm should, at least, respect the principle 'one step up and one step down' – that is, to register who is its immediate supplier and to whom the product is delivered (Hu *et al.,* 2013). Thus, the standard imposes only a minimum level of supply chain transparency and leaves firms free to choose the complexity of the traceability system that they adopt.

With regard to traceability standards issued by industry organisations, the retail sector has played an important role in setting different schemes to facilitate the transparency of trade between sector operators (Giraud-Héraud *et al.*, 2012; Fulponi, 2006). Within European countries, different standards have been introduced by, for example, the British Retail Consortium, Safe Quality Food Program, International Food Standard, the Global Food Safety Initiative and FSSC 22000 Food Safety System Certification.

Furthermore, individual firm standards are often used by food companies and retailers. In Italy, some large meat processors and food retailers have established their own standards. In fact, in the EU, traceability is characterised by the adoption of co-regulatory practices coming from both public and private sectors (Martinez *et al.*, 2007). For example, Amadori, one of the largest Italian chicken-processing firms, has developed a private standard aimed at managing directly the entire supply chain, through the traceability and centralised control of all its phases; while Coop Italia, the largest Italian retailer, has introduced the private standard 'Safe Quality Coop' (Qualità sicura Coop). This standard allows the reconstruction of the history of each individual product, from raw material to finished product. At any time, it offers the possibility to go back to the operator's part of the supply chain (Banterle and Stranieri, 2013).

Inevitably, the proliferation of traceability standards and the lack of harmonisation among them lead to different systems with diverse features. In acknowledging the difficulty of classifying traceability standards, Golan *et al.* (2004) identify three main dimensions: the amount of information recorded (breadth); the sectors of the supply chains involved (depth); and the tracking unit used (precision). In addition to these dimensions, the speed of the information flows within supply chains is also used to define traceability standards, although such a dimension mainly depends on the types of system used to transfer information (McEntire *et al.*, 2010).

Owing to the lack of proper harmonisation of the concept of traceability, we refer to the dimensions identified by Golan *et al.* (2004), in order to capture the different levels of traceability complexity. According to Asioli *et al.* (2014) and Lavelli (2013), the higher the level of breadth, depth, and precision of traceability, the greater the procedures to be implemented and, thus, complexity of these systems. Indeed, it is possible to distinguish between complex standards with stringent rules and procedures, and flexible standards with simple ones.

2.3. Traceability standards and the management of supply chain relationships

Current economic literature on food safety and quality schemes attributes some relevance to the incentives leading food firms to implement traceability standards and to the consequences of their adoption. Among the identified motivations for food firms to implement such standards are management of food safety crises (Pouliot and Sumner, 2013); differentiation of food quality attributes (Manos and Manikas, 2010); enhancement of firm performance (Canavari *et al.*, 2010; Fritz and Schiefer, 2009); regulatory updating (Liao *et al.*, 2011); and improvement of supply chain efficiency in terms of liability distribution (Hu *et al.*, 2013; Hobbs, 2004).

With regard to the consequences of traceability adoption, Ringsberg (2014) outlines how it can be considered an effective tool for the management of different supply chain risks in terms of its ability to increase supply chain transparency. In addition, Bosona and Gebresenbet (2013) describe traceability as a system that can reveal relevant data among economic partners and increase transaction transparency. Moreover, other authors highlight the specific information that can be transmitted by a traceability system such as, for example, on product origin, processing methods, safety and quality characteristics of food products and on the agents of the traced supply chain (Peres *et al.*, 2007).

Because of the increased transaction transparency among the agents of the supply chains, a growing body of literature is referring to traceability standards as alternative forms of governance of vertical relationships, which can reorganise transactions (Grandori, 2015; Bain *et al.*, 2013; Henson, 2011; Tallontire *et al.*, 2011; Banterle and Stranieri, 2008). However, firms' effectiveness in managing information and transactions within supply chains will depend on the traceability standard applied (i.e. on the rules and procedures implemented). In general, the greater the complexity of traceability standards, the greater the amount of information provided by the system and its capacity to efficiently manage transactions.

To the best of our knowledge, there is a gap in understanding of the determinants influencing food firms' choices of different kinds of standards; that is, the motivations leading firms to decide upon the level of transparency to achieve within food supply chains. To fill this gap, we turn to TCE and the current debate on transaction risks, and we consider traceability standards as institutions that can variously affect the coordination of vertical relationships. The effects on vertical coordination depend on the rules applied by the standards, leading to a set of different situations, from low to strong coordination. The adoption of few rules and minimal procedures corresponds to simple traceability standards with a low impact on transaction organisation, owing to the low level of supply chain transparency. More rules and stringent procedures lead to complex traceability standards, which imply more coordinated transactions because of the high supply chain transparency involved.

From a theoretical point of view, the analysis of the relationships between transaction risks and types of traceability standard adopted contributes to the current debate on different types of risk and vertical organisation (Wever *et al.*, 2012). Indeed, the analysis of traceability in the food sector contributes to a better understanding of standards adoption, its effects on vertical coordination and the role of risks. The role of supply chain risks on the adoption of traceability standards can also be revealed in different non-food industries (McEntire *et al.*, 2010). In the automotive industry, for example, traceability is perceived as a means to reduce the risks associated with product defectiveness and to better manage liabilities within the supply chain. In the pharmaceutical industry, traceability is gaining importance due to the frequent use of counterfeit drugs. In this sector, traceability is adopted to reduce the risks of opportunistic behaviour and to guarantee the authenticity of drugs. In the toy industry, traceability is considered as a tool to manage unfair transaction practices and assure the safety of production procedures. Furthermore, in the clothing sector, traceability is used to manage changing consumer preferences in terms of the ethical and environmentally friendly attributes of the products. However, the role of these different risks on the types of traceability standard implemented needs to be further investigated.

3. Theoretical framework and hypotheses

Our study is positioned within the TCE theory and contributes to the existing debate on the relationship between different types of transaction risk on the organisation of vertical relationships, by considering the role of such risks in the adoption of different traceability standards (Billitteri *et al.*, 2013; Wever *et al.*, 2012; Geyskens *et al.*, 2006; Das and Teng, 2001).

TCE assumes that economic actors are affected by bounded rationality and opportunism (Simon, 1945; Williamson, 1975) and that, because of these constraints, they cannot predict in advance all possible contingences surrounding a transaction. Moreover, they will try to take benefits at each other's expense, or claim misleading compliance with the conditions of existing arrangements (Ghosh and John, 1999; Williamson 1991).

These assumptions imply the presence of exchange risks for transacting parties – specifically, the risk of opportunistic behaviour and the shirking of an economic subject involved in a transaction. Thus, in this analysis we consider transaction governance, like traceability standards, not only as a tool to reduce transaction costs, but also as a tool to manage transaction risks (Wever *et al.*, 2012). According to Williamson (1985), such hazards will be high in situations where the governance of the transaction is not effectively aligned with the level of transaction attributes—that is, the level of transaction frequency, asset specificity, and uncertainty.

Transaction frequency relates to how often a certain transaction takes place (Williamson, 1991). In our study, we did not consider this transaction attribute because we refer mostly to recurring vertical relationships, which are managed by different traceability systems. Asset specificity refers to investments that are adopted uniquely to conduct a certain transaction.

According to Klein *et al.* (1978), the specificity of assets occurs when their value decreases outside the transaction for which they have been adopted. Thus, asset specificity increases the bilateral dependency of economic agents and the risk of opportunistic behaviour. Finally, transaction uncertainty can refer both to the inability of economic agents to effectively measure the outcome of a transaction (behavioural uncertainty) and to unexpected changes in the economic environment (environmental uncertainty) (Williamson, 1985). The ineffective capacity of the agents to foresee the realisation of contractual obligations mainly depends on their bounded rationality and leads to the risk of opportunistic behaviour and shirking.

The unpredictability of variation in the economic context in turn implies the inability of economic agents to foresee variations in relevant aspects surrounding the vertical exchanges, which leads to a risk of maladaptation—that is, the risk that the investments and conditions established by the agreements fail, because they are not suitable for adapting to environmental changes (Gulati and Singh 1998; Walker and Weber, 1987). High-level environmental uncertainty involves an increased risk of maladaptation of the transacting parties and, consequently, a higher level of difficulty for economic actors to negotiate formal agreements (Artz and Brush, 2000; Crocker and Masten, 1991). According to Miller (1992), managers have to face different forms of uncertainties, which lead to maladaptation risks. Such risks can be connected both to the specificities of the industry in which firms operate and to the general economic environment; for example, industry risks refer to uncertainties in demand and supply, prices, policy and technology, while general environmental risks may relate to political instability and macroeconomic, social and natural uncertainties.

On the basis of the risks identified above, it is possible to subdivide the transaction risks into internal and exogenous risks. Internal risks refer to all the hazards which depend on the bounded rationality of economic agents and which relate to their behaviour in the execution of transactions (the risk of opportunistic behaviour and of shirking). Williamson (1991) defines such risks as internal, as they can be managed within the transaction through the adoption of a form of governance, which minimises such risks. In general, the higher the internal risks, the greater the probability of adopting forms of transaction governance with a high level of vertical coordination.

Exogenous risks refer to all those hazards that relate to unexpected changes in the institutional environment. These risks do not depend on the behaviour of economic agents, and they can be neither predicted nor managed in advance by specific arrangement conditions. Exogenous risks relate mostly to transacting parties' maladaptation. When risks depend on environmental uncertainty (risk of maladaptation), the debate on the type of governance to adopt is controversial. TCE postulates that economic subjects will adapt better to exogenous sources of transaction uncertainty through hierarchical forms of transaction organisation (Williamson, 1991). However, recent theoretical developments (Miller and Folta, 2002) and empirical findings (Olmos, 2010; Geyskens *et al.*, 2006; Schilling and Steensma, 2002; Das and Teng, 2001; Barney and Lee, 2000; Balakrishnan and Wernerfelt, 1986) do not confirm a positive relationship between the level of environmental uncertainty and hierarchical transaction governance.

Literature has identified different elements that contribute to the increase of internal and exogenous risks. Regarding the former, there is robust empirical evidence on the positive influence of transaction investment specificity on behavioural uncertainty and on the probability of internalising transactions (David and Han, 2004; Leiblein and Miller, 2003; Boger *et al.*, 2001; Dorward, 1999). This positive relationship is mainly related to the high transaction exit barriers due to such specific investments (Ziggers and Trienekens, 1999). Focusing on the agri-food sector, Young and Hobbs (2002) identify process attributes, such as biotechnology and information technologies, as important factors that affect tighter supply chain coordination. Moreover, different authors discuss the positive association between closer vertical coordination and specific investments for product quality attributes within the food supply chain (Ménard and Valceschini, 2005; Raynaud *et al.*, 2005; Hobbs and Young, 2000). Based on the existing empirical evidence we thereby hypothesise:

H1: Higher investment specificity in process attributes results in higher traceability complexity.

In addition, partner asymmetry—the unequal distribution of power and control among transacting parties—has been found to contribute significantly to behavioural uncertainty and its related internal risks. Such misalignment depends on several aspects: asymmetric bargaining power between transacting parties (Panico, 2011; Sheu and Gao, 2014); information asymmetry among transacting parties (Dries *et al.*, 2014; Fischer *et al.*, 2010 Boger *et al.*, 2001; Hobbs, 2004); and the related difficulty in assigning liability rules (Hobbs, 2006; Pouliot and Sumner, 2008). These can all be considered as situations that increase partner asymmetry. In such circumstances, closer vertical coordination is considered as a solution to minimise transaction costs and related risks (Gereffi *et al.*, 2005). Thus, we hypothesise:

H2: Higher partner asymmetry results in a higher level of traceability complexity.

Moreover, trust between transacting parties is considered an important aspect for managing internal risks and the governance of vertical relationships (Das and Teng, 2001); however, different trust-related issues have been identified. Fischer (2013), Van de Vrande *et al.* (2009) and Wang and

Zajac (2007) found that long-term business relationships enhance trust. Saak (2012) discusses firm reputation as being a source of trust in vertical relationships. The higher the trust among economic agents, the lower the necessity to monitor transactions through highly coordinated forms of transaction governance because of the low level of internal risks (Zak and Knack, 2001). Hence, we hypothesise that:

H3: Higher trust in vertical relationships results in lower levels of traceability complexity.

The resilience of supply chains is affected by several exogenous risks. In the food industry, such risks relate mostly to the availability of substitute goods and to the frequent and high level of public regulation interventions related to food safety (Matopoulos *et al.*, 2007; Schilling and Steensma, 2002). The presence of substitute goods implies increased volatility of demand (Pettit *et al.*, 2010). In the food sector, such uncertainty mainly comes from rapid changes in consumer quality preferences that food firms try to manage through the adoption of quality certification strategies. There exist different kinds of quality and safety standards aimed at gaining market recognition because of the multitude of quality food attributes which can be certified (Lee *et al.*, 2011): for example, systems for recognising the presence/absence of certain ingredients, the sustainability of food production processes, the authentication of raw materials and ethical features of agricultural production all aim to impact strongly on consumer preferences, by tracing specific product characteristics (Hussein *et al.*, 2015). However, the need to constantly manage demand volatility leads firms to implement voluntary standards with rules that can easily accomplish changing consumers' needs (Zhang *et al.*, 2016). In accordance with recent economic literature, which attests a negative relationship between exogenous risks and levels of transaction coordination (Varacca *et al.*, 2013; Billitteri *et al.*, 2013; Wever *et al.*, 2012; Judge and Dooley, 2006; Das and Teng, 2001), we test the following hypothesis:

H4: Rapid changes in consumer quality preferences result in a lower level of traceability complexity.

The growth in food safety incidents threaten consumers' trust in the quality attributes of products. For example, the cases of bovine spongiform encephalopathy, dioxin in chicken feed and foot and mouth disease and many other issues, like poisoning from Salmonella, Campylobacter and Escherichia coli, have increased consumer concerns related to the safety of food. To tackle this problem, an increasing number of regulations regarding food production has been introduced by public authorities (Aung and Chang, 2014). The rapid changes in the food safety normative framework have increased firms' uncertainties regarding the level of safety requirements to implement in vertical exchanges (Fulponi, 2006). As a consequence, an increasing number of different forms of voluntary standards has been registered within the market to facilitate the accomplishment of public regulations (Trienekens and Zuubier, 2008; Henson and Caswell, 1999). Manning and Soon (2016) point out the importance of firms' flexibility in adapting to market changes and building resilience within food supply chains. By acknowledging the role of food firms in the implementation of different public safety standards and the current debate on exogenous risks on the organisation of vertical relationships, we test the following hypothesis:

H5: Regular changes in food safety regulatory frameworks result in a lower level of traceability complexity.

As to exogenous risks related to the general environment, the geographical distance between transacting parties has been considered as a source of these types of risks (Lo Nigro and Abbate, 2011). A greater geographical distance between transacting parties implies greater differences in terms of culture, regulations, technological standards, and business practices, thus leading to greater difficulty in transaction coordination and a higher probability that simple forms of transaction governance are adopted. We therefore hypothesise:

H6: Suppliers' geographical proximity results in a higher level of traceability complexity.

4. Methodology

4.1. Data

The analysis is based on the entire population of firms in Italy with voluntary traceability schemes based on ISO 22005. Indeed, such a standard allows firms to adopt diverse traceability schemes with different degrees of complexity. In order to build the population of Italian firms certified with this voluntary standard, we first consulted the Accredia portal. Accredia is the Italian Accreditation Body appointed by the state to perform accreditation activities. The national body is responsible for accreditation in compliance with the international standards and harmonised series of European norms.

From the portal, we extracted the 15certification organisations accredited by Accredia, which operate in the agri-food sector. These were: AQA (Agenzia per la Garanzia della Qualità in Agricoltura); CCPB (Consorzio per il Controllo dei Prodotti Biologici); CDQ Italia (Certificazioni di Qualità Italia); Cermet; Certiquality; Check Fruit; CSQA (Certified Software Quality Analyst); Bureau Veritas Italia; Valoritalia; DNV Italia (Det Norske Veritas); Ecepa (Ente certificazione prodotti agroalimentari); Istituto Mediterraneo di Certificazione; Parco Tecnologico dell'Umbria; SGS Italia; and BVQI Italia. We then telephoned these organisations to ask if they had food firms certified by ISO 22005. Of these, 74% declared that they had firms applying this kind of standard.. The list of certified Italian food firms was obtained by consulting both the lists provided by the above certification organisations (by fax and mail) and their websites. A questionnaire was conducted on the firms specialising in food processing and certified by ISO 22005 to test the determinants that lead food firms to apply different kinds of traceability rules within the certified food supply chains. The firms totalled 216; the refusal rate was 16%. Owing to missing data, 146 questionnaires were used for the analysis, corresponding to 68% of Italian firms certified by ISO 22005.

Before the survey, we conducted a pilot test to check comprehension of the questions and the length of the interviews. The duration of the survey was almost six months, owing to difficulties in contacting the appropriate personnel in charge of supply chain management and in planning interview time schedules with them. The questionnaire was based on closed questions (apart from the number of employees). Each interview lasted around 45 min. During the interviews an explanatory introduction was devoted to specifying the details of the analysis and the significance of specific questions. From the questionnaire, we derived the variables, which are reported in Table 1. In addition, and in accordance with Armstrong and Overton (1977), we ruled out significant non-response bias from the results of this analysis. Comparisons of average values and of the structure of the responses did not identify significant differences between questionnaires that were returned early and those that were returned later (Verworn, 2009).

4.2. Variables and methods

The questionnaire adopts a multiple-choice and rating-scale format to obtain answers as numerical variables (Kalton, 1983). The first part of the questionnaire concerns the types of traceability system in terms of breadth, precision and depth (Golan *et al.*, 2004) and the general characteristics of the firms interviewed (i.e. income and sector). The second has variables aimed at capturing the internal risks perceived by those who were interviewed. The third part contains variables to measure the exogenous risks perceived by the firms. The variables measuring internal and exogenous risks are related to the situation *ex ante* the introduction of a voluntary traceability system. Table 1 summarises all variables used: their descriptions, type, scale, average value, and standard deviation.

To measure the kind of voluntary traceability adopted (VTRi) by food firms, we constructed an ordinal variable (scale 1–3) obtained by adding the scores of the questions related to the rules adopted to implement voluntary traceability in terms of breadth, depth and precision (Table 1). The breadth of the systems was measured by asking about the increase in the amount of recorded information exchanged along the supply chain with the introduction of voluntary traceability. The scores ranged from 1 to 4 (where 1 = 'no information increase recorded' and 4 = 'significant increase of information recorded'). The depth of traceability was measured by asking interviewees about the identification of the sectors involved in the voluntary system. The scores ranged from 1 to 3 (where 1 = 'agriculture or agriculture and food industry'; 2 = 'inputs, agriculture and food industry'; and 3 = 'inputs, agriculture, food industry and retailing'). Precision was measured by asking participants about variations in batch dimensions to implement voluntary traceability (where 1 = 'the traced unit did not change compared to that of Reg. 178/2002'; 2 = 'the system refers to a reduced external tracking unit'; 3 = 'the traced unit refers to a reduced external and internal tracking unit'; and 4 = 'the traced unit refers to the identification of each single supplier involved in the production of such unit'). For the measurement of the dependent variable, we did not consider the speed of traceability, even if it is another dimension characterising traceability standards. The reason for the exclusion of such a variable is related to the fact that the food sector does not adopt highly innovative means to manage information within the supply chain. Thus, it does not represent an effective explanative element to capture the diversity of existing traceability standards (Borit, 2016; Badia-Melis et al., 2015; McEntire *et al.*, 2010).

On the basis of the results obtained, we constructed three different levels of traceability system complexity: 'low traceability rules' (scores from 3 to 6); 'medium traceability rules' (scores from 7 to 9); and 'high traceability rules' (scores from 10 to 12). Low traceability rules refer to flexible traceability systems, whereas high traceability rules relate to complex traceability systems.

<insert Table 1 about here>

Among the control variables (C_{ji}) we considered each firm's size because such a dimension is quite common in research studies with a similar aim (Pozo and Schroeder, 2016). Firm size (C_{1i}) is operationalised using the number of employees. We control also for the geographical location (C_{2i}) of the firm to investigate the possible effects of the area where the firms are established (north, central or south Italy) on the type of traceability adopted. To check for inter-sector differences (C_{3i}), we introduced four dummy variables—fresh and processed meat, processed fruit and vegetables, dairy, and wine—with 'other sectors' (the reference category) to control for these differences.

Finally, we introduced the dummy variable 'capital-based company' (C_{41}) to control for the status of the firm and to explore the impact of a more complex firm structure on the traceability system with respect to simpler organisational forms (Table 1).

The independent variables have been selected in accordance with the economic literature with the aim of using factor proxies to explain the internal and exogenous risks (Billitteri *et al.*, 2013). As discussed in section 3, internal risk variables considered are investment specificity (IS_i), partner asymmetry between transacting parties (PA_{ji}), and trust between them (T_{ji}). Exogenous risk variables are expressed by variations in consumers' preferences for quality food attributes (P_i), the intensity perceived in the variation of safety regulatory measures (S_i), and the geographical proximity of suppliers (SP_i).

TCE pinpoints transaction-specific investments as drivers of high degrees of opportunistic behaviour. To investigate IS_i, we asked firms whether they conducted physical investments together with suppliers for the implementation of traceability. The answers are on a dichotomous scale, whereas PA_{ji} along the supply chain is measured through three variables in accordance with Sheu and Gao (2014), Dries *et al.* (2014) and Hobbs (2006). More precisely, respondents were asked to state their level of agreement with statements investigating the asymmetry in contractual bargaining power perceived among supply chain agents (PA_{1i}, scale 1–4), the perceived difficulty in liability distribution among the agents of the supply chain (PA_{2i}, scale 1–4), and the level of information transparency among transacting parties (PA_{3i}, scale 1–4).

The level of trust was measured by three other variables (T_{ji}) in accordance with Fischer (2013) and Saak (2012). The first (T_{1i}) measures the level of non-confidence in suppliers (scale 1–4); the second (T_{2i}) deals with the reputation of main suppliers (scale 1–4); and the last (T_{3i}) refers to the length of time of inter-firm relationships (scale 1–4).

To measure the changes perceived in the safety regulatory framework, we asked managers to express a judgement on the statement 'The food safety rules change' (S_i, scale 1–4). To measure the perceived changes in consumer preferences, we asked managers to express a judgement on the statement 'Consumers' preferences towards product quality attributes change' (P_i, scale 1–4). The geographical proximity of the main suppliers (SP_i) was also measured by a 1–4 rating scale. To measure this variable, we asked managers to indicate the geographical closeness of their firm's main suppliers.

4.3. The model

We conducted an ordinal regression model to test our hypotheses. Because our dependent variable VTR_i is an ordinal variable, a proportional odds logistic specification is recommended, according to McCullagh (1980). The ordinal logistic model is defined as:

$$logit[P(y_z \leq i)] = \alpha_i + \beta_j C_{jz} + \beta_j IS_z + \beta_j PA_{jz} + \\ +\beta_j T_{jz} + \beta_j S_z + \beta_j P_z + \beta_j SP_z, i = 1,2, \dots, k-1 \quad [1]$$

where $P(y_z \leq i)$ is the cumulative probability (i.e. the probability that the *z*th individual is in the *i*th or higher category) and β is a vector of logistic coefficients of the *j*th control and independent variables, and tells us how a one-unit increase in the control/independent variable increases the log odds of being higher than category i. The intercept a_i varies between categories and satisfies the constraints $a_1 \leq a_2 \leq \cdots \leq a_{k-1}$. The individuals in the sample are assumed to be categorised independently of each other. We used the *polr* command from the MASS package and the *clm* command from the ordinal package in the R 3.2.2 software to estimate an ordinal logistic regression model. The command name comes from proportional odds logistic regression, highlighting the proportional odds assumption in our model. The coefficients from the model can be difficult to interpret because they are scaled in terms of logs. Another way to interpret logistic regression models is to use the antilog to estimate the coefficients into odds ratios (OR). This procedure allows a better understanding and comparison of coefficients in models 4 and 5.

Furthermore, we operationalised the Akaike information criterion, the log likelihood and the log likelihood ratio (LR) test to evaluate the goodness of fit of the models. As a base model to compare our results against, we first present the outcome with only the control variables. Model 1 in Table 3 represents the effect of the control variables on the dependent variable, VTR. Model 2 shows the results of the controls plus internal risk variables. Model 3 introduces the results of the controls plus exogenous risk variables. Model 4 presents the results for the full model when all variables are entered (control variables, internal risk variables and exogenous risk variables). Model 5 introduces the pairwise interaction terms between internal risk variables and exogenous risk variables.

Finally, we tested the robustness of the results and the assumption of the proportional odds against alternative model specifications. One way to do this is by comparing the proportional odds logistic model with a multinomial logit model. The latter is typically used to model unordered variables, while the former is nested in the multinomial model; thus, we performed an LR test to see if the models are statistically different, but we found no significant differences. Moreover, the results of the multinomial model are consistent with those presented in Table 3.

5. Results

With regard to firms' general characteristics, 38% of the sample is composed of companies with fewer than 20 employees; 22% of the firms have between 20 and 50 employees; 14% have between 50 and 100 workers; 10% have between 100 and 150; and 16% have more than 150. Of the companies interviewed, 9% report an income of less than one million euros; 36% have a turnover between one and 10 million euros; 23% between 10 and 25 million; 13% between 25 and 50 million; 4% between 50 and 100 million; and 15% have a turnover of more than 100 million euros. The structural features of the sample reflect those of the Italian and European food industry, which is composed of both small and large firms that compete in the same market.

The majority of the firms are located in northern Italy (about 80%); the rest are divided equally between central and southern Italy. The sectors most represented within the sample are fresh and processed meat (22%); processed fruit and vegetables (21%); dairy, including milk, butter and cheese (26%); and wine (13%). The remaining sectors involve processed fish (2%); olive oil and fats of vegetable origin (4%); processed cereals (3%); bread and pastries (2%); sugar and sweeteners (5%); and other food products (2%). Finally, capital-based companies make up 49% of our sample, while the rest of the sample is composed of partnerships (16%) and cooperatives (35%).

The correlations in Table 2 do not suggest multicollinearity, since correlations among independent and control variables are well below the value of .50; however, we undertook some additional tests to detect possible multicollinearity. We regressed each independent variable on all the other independent variables; this test did not indicate multicollinearity. In addition, we checked for the existence of multicollinearity by computing the variance inflation factors (VIFs) for all the models and found multicollinearity not to be a problem. The VIF values were always lower than the cut-off point of 5 (O'Brien, 2007).

<insert Table 2 about here>

Table 3 presents the proportional odds logistic coefficient estimates for the ordinal regression models. The overall fit of the model increases compared to the baseline, but also with respect to models 2 (controls plus internal risk variables) and 3 (controls plus performance risk variables), denoting that the full model better fits our data. The LR test shows that model 4 improves significantly against any other model (Pr > LR test is 0.001). Therefore, the LR test indicates that model 5 compared to model 4 has more explanatory power (Pr > LR test is 0.01). In other words, the introduction of the three interaction terms is important in explaining the type of traceability adopted by the food firms.

Model 1 is the baseline model with only the control variables. The coefficient estimates of the variables 'Firm's size' ($p < 0.01$) and 'Capital-based company' ($p < 0.001$) are statistically significant, suggesting that larger firms are more likely to adopt traceability systems with a low level of complexity, while capital-based companies are more likely to adopt higher traceability complexity. By contrast, the variables measuring the geographical locations of the firms and their core sectors turn out to be non-significant. This result seems to support the view that there are no significant differences in traceability standards among Italian firms in terms of where the firms operate and their different sectors, except for the dairy sector ($p < 0.05$), which shows a higher probability to adopt traceability systems with a low level of complexity. This is related to the specificities of the dairy supply chains, where production flows cannot be easily managed by separate tracking units due to the characteristics of the products. As expected, the meat sector shows a higher average value compared to other sectors, although we have no conclusive statistically significant evidence. This is related both to the characteristics of meat products, which are easily identified by separate tracking units, and to the existing European meat regulations, which impose a complex traceability.

Although we focus on the full model (4), we also provide the baseline model (1), a model that includes only internal risk variables (model 2), and model 3, which includes only the exogenous risk variables, to show that the coefficients and signs remain robust over the different models and that multicollinearity is not a particular problem in these regressions. The estimates of the coefficients of the control variables remain stable compared to the baseline model and models 2 and 3. Specifically, 'Firm's size' ($p < 0.05$) is negatively correlated to the complexity level of traceability system adopted, whereas 'Capital-based company' ($p < 0.10$) is positively correlated to the dependent variable.

In terms of internal risks, the variable 'Investment specificity' shows a positive and significant relationship with the complexity level of traceability rules, thus confirming H1. Regarding partner asymmetry, 'Asymmetric bargaining power', 'Liability' and 'Information exchanged' present positive coefficients in accordance with the literature (David and Han, 2004) and with model 2 (only controls plus internal risk variables), but they are not statistically significant. In this case, H2 cannot be confirmed. As to partner trust, 'Suppliers' confidence' is positive and statistically significant ($p < 0.001$), while 'Reputation' ($p < 0.1$) and 'Inter-firm relationship experience' ($p < 0.001$) are significant and negatively linked to the dependent variable. When the reputation of suppliers is high, the probability of choosing a traceability system with a low level of complexity increases (i.e. a standard entailing lower coordination mechanisms). Moreover, the variable ‘Inter-firm relationship experience’ is negatively related to the level of traceability complexity implemented by food firms, revealing that stable vertical relationships increase the level of trust between transacting parties, and decrease the risk of opportunistic behaviour and the necessity to adopt complex rules to organise transactions. Indeed, higher levels of trust result in lower levels of traceability complexity, thus confirming H3.

With regard to exogenous variables, those considered in the ordinal regression are all statistically significant. The variables ‘Food safety rules’ ($p < 0.01$) and ‘Food quality preferences’ ($p < 0.05$) are significant, and negatively related to the dependent variable. Thus, the higher the perceived changes in the food safety regulatory framework and in consumer quality preferences, the higher the probability that low levels of traceability complexity are adopted, thus confirming H4 and H5. Moreover, ‘Suppliers’ proximity’ is significant, and positively correlated to the type of traceability, meaning that firms geographically close to their main suppliers are more likely to adopt complex traceability systems, thus confirming H6.

In model 5, we included in the analyses the interaction terms between internal risk variables and exogenous risk variables to evaluate possible significant moderating effects. To achieve our goal, we standardised risk variables prior to calculating their interaction terms, to avoid unnecessary multicollinearity (Aiken and West, 1991), and we performed a stepwise technique for optimising the model. We report only those interaction terms remaining after the stepwise procedure (Billitteri *et al.*, 2013) and focus the comments only on the interaction terms, because the results for the other variables are substantially the same as in model 4.

The interaction between ‘Liability’ and ‘Suppliers’ proximity’ is significant ($p < 0.1$). The OR coefficient (0.62) is not comparable with that of ‘Liability’, because it is not significant. However, it is lower than that of ‘Suppliers’ proximity’ (5.34), underlining the moderating effect of the internal risk component (‘Liability’) on the exogenous risk one (‘Suppliers’ proximity’). The interaction between ‘Information asymmetry’ and ‘Food quality preferences’ is significant ($p < 0.1$). While the OR coefficient (0.68) is not comparable with that of ‘Information asymmetry’, because it is not significant, it is slightly lower than the coefficient of ‘Food quality preferences’ (0.68), showing, in this case, no moderating effect of the exogenous risk variable on the internal risk one.

Finally, the interaction between ‘Suppliers’ confidence’ and ‘Food safety’ is significant ($p < 0.01$). The OR coefficient (2.29) is lower than that of ‘Suppliers’ confidence’ (3.80) and is greater than that of ‘Food safety rules’ (0.68). In this case, the presence of a low level of ‘Suppliers’ confidence’ (an internal risk component) increases the likelihood of a higher level of traceability complexity, moderating the effect of high 'Food safety rules' (an exogenous risk component). On the other hand, a high level of 'Food safety rules' decreases the likelihood of higher traceability adopted, moderating the effect of 'Suppliers' confidence'.

<insert Table 3 about here>

6. Concluding remarks

In recent years, different voluntary traceability standards have been introduced within the food sector. Even if a specific legal framework concerning mandatory food traceability is implemented in the EU, firms can choose to adopt additional voluntary traceability. These have been elaborated by collective organisations such as non-profit organisations, or groups of individuals belonging to the same economic sector and by private firms. Indeed, it is possible to observe a variety of different traceability standards that imply different costs for their implementation and have effects on the reorganisation of food supply chains.

The present analysis contributes to the explanation of the determinants leading firms to choose among different types of traceability standards. These standards are considered as institutions that can modify the levels of vertical coordination, depending on the complexity of the standards adopted. To the best of our knowledge, this article is among the first attempts to investigate the role of risk on firms' strategic decisions related to the adoption of different voluntary supply chain standards, such as traceability.

Empirical results highlight that the perceived risks (both internal and exogenous) for food firms in vertical relationships can help to explain their mechanisms for the adoption of different traceability rules. Ordinal regression demonstrates that, in general, there is a positive link between internal risks and the decision to implement complex traceability rules in accordance with the concepts of TCE literature. Moreover, the analysis also shows a negative relationship between the perceived exogenous risks and the level of traceability complexity. Indeed, exogenous transaction risks seem to lead to the implementation of a system that does not imply strong coordination.

The results achieved in the analysis are sector specific, owing to the particular features of food products and their related market. Typically, food is perishable and is not easily standardised; it is often embedded in local systems; and its safety and quality attributes exert a strong influence on supply chain strategies. Furthermore, there are many food firms of small dimensions. However, the insights regarding the relations between transaction risks and vertical coordination could also be relevant in other sectors with similar characteristics.

From a managerial perspective, this article confirms that supply chain standards, such as traceability, can be considered as alternative forms of transaction governance and can be used by firms as effective tools to manage transaction risks associated with supply chain relationships. The analysis also gives managerial insights on the key determinants affecting the adoption of different traceability standards, and suggests potential implications for decision makers.

Small agri-food firms are more likely to use complex and stringent traceability standards to coordinate their vertical relationships and to reduce any opportunistic behaviour of supply chain agents. This can be related to two different aspects: on the one hand, small businesses can adopt traceability standards required by retailers in order to become their suppliers; while on the other, small firms focused on speciality foods and high-quality products are prone to defending their brand equity through standards that can effectively distribute liabilities among the agents of the supply chain, and hence avoid compliance risks, through greater transparency. Thus, the adoption of complex traceability can contribute to solving these coordination problems by strengthening vertical relationships.

By contrast, larger firms are more likely to adopt flexible traceability standards. This is because these kinds of firms operate globally, whereby suppliers and customers operate in different economic and political contexts. Indeed, the probability of managing exogenous risks is high and implies the necessity to implement standards that help to manage these uncertainties. In this situation, firms prefer to minimise the risk of their maladaptation by using standards that can be more flexible towards unexpected changes in the economic environment.

The analysis highlights that cooperatives prefer to use flexible solutions to manage transactions, which do not imply robust changes in the organisation of supply chain governance. Such results are in line with TCE theory, where vertical integration reduces internal risks and, thus, the need to adopt complex standards.

Our findings also provide an interpretative base for managers, who have to estimate the risks associated with vertical relationships within supply chains and to give initial insights on the role of standards for the management of such risks. Managers should take into serious consideration two different transaction risks when deciding on the standards to adopt: that is, internal and exogenous risks. More precisely, if exogenous risks are present, the traceability adopted should not imply a strong reorganisation of vertical relationships. In this case, managers seem to want standards flexibility to respond more rapidly and effectively to unexpected changes in market dynamics. On the other hand, if the firms face internal transaction risks, leaders have to achieve a better management of vertical relationships and decrease the opportunistic behaviour of supply chain agents. In this case, results suggest adopting complex rules and procedures in order to coordinate vertical relationships. Thus, in case of internal transaction risks, traceability standards are adequate solutions for fostering an effective management of the supply chain. Such results add to the existing literature (Fischer *et al.*, 2010) in explaining the situations in which voluntary traceability standards can be considered as effective instruments to reach more sustainable vertical relationships, in terms of improved cooperative behaviour and transaction transparency.

On the moderating effects of internal and exogenous risks regarding the type of traceability to adopt, the analysis does not entirely confirm the moderating effect of internal risks on the exogenous ones in line with the findings of Billitteri *et al.* (2013). The presence of minor moderating effects suggests that decision makers tend to manage these two main forms of risks as independent issues. Thus, managers simplify supply chain risk management through a separate assessment of risk categories, without considering a more integrated view of them. Of course, we are not suggesting that this is the 'optimal' vertical relationship governance strategy when adopting traceability standards, because we are not linking and evaluating these strategies to firm performances. A more integrated and multidimensional view of risk categories could be useful to achieve better vertical coordination and financial performances. However, the latter could be understood only by linking it with risk categories and traceability standards.

This paper also suggests policy implications. The European regulation on traceability refers both to mandatory and voluntary rules. The mandatory framework is based on a specific complex standard for meat products and on simple traceability for all other agri-food products. As meat products are characterised by strong public regulation, there is no need to adopt complex voluntary traceability standards to reduce the opportunistic behaviour of firms along the supply chain. This is in accordance with Raynaud *et al.* (2005), who point out that market-like governance forms, such as flexible traceability standards, are more likely to be implemented when public safety rules play a significant role. Apart from the bovine meat firms, all the other agri-food companies can decide to adopt different kinds of voluntary traceability standards, both flexible and complex. The adoption of complex voluntary rules allows firms to reach a more efficient coordination of vertical relationships and does not require further public intervention. By comparison, the implementation of flexible voluntary standards has led to a proliferation of different traceability rules, which generate difficulties related to the effectiveness of traceability systems. Indeed, public intervention could harmonise these flexible standards by providing a general framework composed of simple rules to be followed by food firms.

This study presents some limitations. We used a cross-sectional analysis to investigate the links between transaction risks perceived by supply chain agents and the traceability systems adopted. As such, when analysis is applied to a single European country, it limits the generalisability of the results. Future surveys providing longitudinal data could enhance our understanding of the transaction risks and traceability standards, in which case a longitudinal regression would better represent these dynamics. Moreover, the effect of the simultaneous presence of different transaction risks on the governance of vertical relationships and on food standards adoption needs further investigation.

Future research can focus on the interactions among different transaction risks in affecting the decision concerning the type of traceability standard to adopt. Another interesting future research area relates to a deeper comprehension of the optimal behaviour of agri-food firms in handling supply chain relations, through the analysis of the link between alternative governance strategies connected to voluntary standards and firm performances. Moreover, future studies could also investigate the relations between the adoption of standards, risks, and vertical coordination in those sectors that present similarities with the food industry.

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Variables	Variable description	Variable type	Scale/ items	Mean	St.dev.
Dependent variable					
Traceability adopted (VTR_i)	Kind of voluntary traceability adopted (1 = low traceability; 2 = medium traceability; 3 = high traceability)	**ordinal**	1 - 3	1.83	0.68
Control variables					
Firm's size (C_{1i})	Number of employees of the firm	**numeric**	1 - 1300	103.45	215.18
Firm's geographical area (C_{2i})	Geographical location of the firm (1 = North Italy; 2 = Central Italy; 3 = South Italy)	**factor**	1 - 3		
Firm's sector (C_{3i})	The core sector where the firm operates (1 = Other; 2 = Meat; 3 = Dairy; 4 = Vegetables; 5 = Wine)	**factor**	1 - 5		
Firm's status (C_{41})	The type of firm (1 = Capital based company; 0 = Other)	**dummy**	0 - 1	0.49	0.50
Explanatory variables					
Investment specificity (IS_i)	Physical investments along the supply chain (1 = Yes; 0 = No)	**dummy**	0 - 1	0.41	0.49
Contractual bargaining power (PA_{1i})	The voluntary traceability was imposed by customers (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	1.93	1.05
Liability distribution (PA_{2i})	There is a problem in liabilities assignment among supply chain agents (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	2.50	1.12
Information exchanged (PA_{3i})	The information exchanged during transactions is: 1 = low; 2 = medium; 3 = high; 4 = very high	**ordinal**	1 - 4	3.51	0.85
Suppliers' confidence (T_{1i})	Firm does not trust its suppliers (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	2.49	1.08
Reputation (T_{2i})	Firms' main suppliers have a good reputation (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	3.11	0.98
Inter-firm relationship experience (T_{3i})	The economic relationship with firms' main suppliers last more than one year (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	3.27	0.96
Food safety rules (S_i)	The food safety rules change (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	2.60	1.06
Food quality preferences (P_i)	Consumers' preferences towards product quality attributes change (from 1 = strongly disagree to 4 = strongly agree)	**scale**	1 - 4	2.58	1.14
Suppliers' proximity (SP_i)	Geographical closeness of firms' main suppliers (1 = low-international market; 2 = medium- national market; 3 = high-local market; 4 = very high – close to the firm)	**ordinal**	1 - 4	2.52	1.10

Table 1: Variables and descriptive statistics

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*Traceability adopted*	1.00																				
2	*Firm's size*	-.20*	1.00																			
3	*Geo area_north (dummy)*	-.00	.14	1.00																		
4	*Geo area_centre (dummy)*	.00	-.14	-.45**	1.00																	
5	*Geo area_south (dummy)*	-.08	-.23**	-.31**	.31**	1.00																
6	*Sector_other (dummy)*	.19*	.05	.07	-.07	-.15	1.00															
7	*Sector_meat (dummy)*	-.28**	.10	.15	-.15	-.11	-.33**	1.00														
8	*Sector_dairy (dummy)*	.05	-.13	-.09	.09	.11	-.28**	-.30**	1.00													
9	*Sector_vegetables (dummy)*	-.04	.05	.15	-.15	-.11	-.22**	-.24**	-.20*	1.00												
10	*Sector_wine (dummy)*	.11	-.09	-.32**	.32**	.30**	-.23**	-.26**	-.22**	-.17*	1.00											
11	*Capital-based company (dummy)*	.44**	.24**	.15	-.15	-.17*	.20*	-.16	.00	-.11	.06	1.00										
12	*Investment specificity (dummy)*	.48**	-.20*	.04	-.04	-.02	.23**	-.25**	-.01	-.00	.05	.45**	1.00									
13	*Contractual bargaining power*	.28**	-.06	.09	-.09	-.14	.14	-.03	-.05	-.09	.03	.14	.13	1.00								
14	*Liability distribution*	.35**	.012	-.16	.16	0.35	-.01	-.04	.07	-.16*	.14	.28**	.16	.19*	1.00							
15	*Information exchanged*	-.01	-.06	-.00	.00	.05	-.04	.12	.06	-.09	-.08	-.01	-.13	.03	.03	1.00						
16	*Suppliers' confidence*	.53**	-.00	-0.02	.02	-.08	.08	-.07	.08	-.09	-.01	.38**	.38**	.15	.28**	-.03	1.00					
17	*Reputation*	-.07	0.07	-.06	.06	-.01	-.04	.06	-.01	-.03	.02	-.01	-.03	.09	.08	.10	.05	1.00				
18	*Inter-firm relationship experience*	-.34**	.26**	.08	-.08	-.12	-.18*	.21**	.06	-.00	-.12	.01	-.19*	-.00	.03	.09	-.17*	-.02	1.00			
19	*Food safety rules*	-.28**	-.00	.05	-.05	-.08	.01	.02	-.04	.02	-.02	-.14	-.09	-.10	-.06	.11	.02	.01	.10	1.00		
20	*Food quality preferences*	-.36**	.015	-.08	.08	.05	-.22**	.19*	-.05	.07	.02	-.26**	-.15	-.08	-.26**	.09	-.20*	.18*	.08	.06	1.00	
21	*Suppliers' proximity*	.56**	-.22**	-0.02	.02	-.04	-.02	-.13	-.01	.12	.08	.10	.27**	.24**	.19*	-.01	.22**	.01	-.12	-.18*	-.08	1.00

Note: Spearman's correlation; Significance levels are ** p<0.01. * p<0.05

Table 2: Correlation matrix

Dependent variable - Traceability adopted (*VTR*)	*Ordinal logistic regression models*						
	Base Model (i)	*+ Int. risks (ii)*	*+ Ext. risks (iii)*	*Full model (iv)*		*Full model (v) with interactions*	
Intercepts	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*O.R.*	*Coeff.*	*O.R.*
VTR 1|2	-0.77	-1.49	-0.35	-1.45		-0.15	
	(0.54)	(1.47)	(1.12)	(1.99)		(2.11)	
VTR 2|3	2.36***	3.45*	4.13***	5.60*		7.21	
	(0.58)	(1.56)	(1.19)	(2.19)		(2.39)	
Control variables							
Firm's size	-0.00**	-0,00**	-0.00†	-0.00*	0.99	-0.00*	0.99
	(0.00)	(0.00)	(0.00)	(0.00)		(0.00)	
Geo area_centre (Yes=1)	0.93	0.72	0.93	1.15	3.16	1.46	4.30
	(0.75)	(0.96)	(0.84)	(1.13)		(1.19)	
Geo area_south (Yes=1)	-0.59	-1.21	-0.61	-1.54	0.21	-2.06†	0.12
	(0.71)	(0.88)	(0.81)	(1.04)		(1.17)	
Sector_meat (Yes=1)	-0.04	-0.21	0.15	-0.31	0.73	-0.34	0.71
	(0.57)	(0.69)	(0.65)	(0.88)		(0.91)	
Sector_dairy (Yes=1)	-1.29*	-1.00	-1.29†	-1.45	0.23	-1.49	0.22
	(0.58)	(0.73)	(0.68)	(0.95)		(1.06)	
Sector_vegetables (Yes=1)	-0.37	-0.34	-0.14	-0.36	0.69	-0.31	0.73
	(0.57)	(0.70)	(0.63)	(0.85)		(0.94)	
Sector_wine (Yes=1)	-0.51	-0.30	-0.92	-1.10	0.33	-0.86	0.42
	(0.65)	(0.80)	(0.76)	(1.00)		(1,12)	
Capital-based company (Yes=1)	1.85***	1.12*	1.71***	1.13†	3.11	1.29*	3.62
	(0.40)	(0.49)	(0.45)	(0.60)		(0.64)	
Explanatory variables							
Investment specificity (Yes=1)		0.96†		0.86	2.38	0.76	2.15
		(0.52)		(0.61)		(0.67)	
Contractual bargaining power		0.41*		0.17	1.18	0.33	1.39
		(0.20)		(0.25)		(0.27)	
Liability distribution		0.59**		0.34	1.40	0.41	1.50
		(0.21)		(0.26)		(0.29)	
Information exchanged		0.11		0.26	1.30	0.33	1.38
		(0.26)		(0.31)		(0.32)	
Suppliers' confidence		0.95***		1.19***	3.30	1.34***	3.80
		(0.25)		(0.33)		(0.36)	
Reputation		-0.45*		-0.42†	0.65	-0.31	0.73
		(0.21)		(0.25)		(0.26)	
Inter-firm relationship experience		-1.12***		-1.08***	0.33	-1.27***	0.28
		(0.24)		(0.29)		(0.33)	
Food safety rules			-0.43*	-0.65**	0.52	-0.78**	0.45
			(0.19)	(0.25)		(0.28)	
Food quality preferences			-0.57**	-0.52*	0.59	-0.37†	0.68
			(0.18)	(0.25)		(0.22)	
Suppliers' proximity			1.35***	1.48***	4.42	1,68***	5.34
			(0.23)	(0.32)		(0.35)	
Interactions							
*Liability*Suppliers' proximity*						-0.47†	0.62
						(0.28)	
*Information asymmetry*Food quality pref.*						-0.38†	0.68
						(0.23)	
*Suppliers' confidence*Food safety rules*						0.83**	2.29
						(0.31)	
No. of observations	146	146	146	146		146	
Akaike Information Criterion (AIC)	260.28	198.91	202.41	158.07		152.62	
Log likelihood (df)	-120.14 (10)	-82.45 (17)	-88.21 (13)	-59.04 (20)		-53.31 (23)	
LR test (change over the reference model)		75.37***	63.87***	122.21***		11.49**	

*Notes: Standard errors are in parentheses; Significance levels are *** p<0.001, ** p<0.01, * p<0.05, † p<0.1; link=logit; "North" reference level for geo area; "Other" reference level for sector; Likelihood-ratio (LR) test: models 2–4 vs. model 1 and 5 vs. model 4*

Table 3: Ordinal regression results