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On the linkages between traceability levels and expected and actual traceability costs and benefits in the Italian fishery supply chain

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ABSTRACT

EC Regulation 178/2002 introduced mandatory traceability for all food operators, but they can choose the level of traceability. We propose a model incorporating three indices of traceability – breadth, depth and precision – that affect costs and benefits. We empirically test the model by regression analyses, using data collected on a sample of Italian fish processors. While higher precision corresponds with larger perceived benefits, an increasing traceability breadth raises costs. A measure of the extent of the discrepancy between expected and actual costs and benefits is also established. Implications are discussed in light of future uptake of continuously advancing traceability technologies.

1. Introduction

Consumers increasingly demand food with higher safety levels and transparency throughout the supply chain. At the same time, food industry, in particular the fisheries sector has rapidly internationalized and expanded international trade (Donnelly, Thakur, & Sakai, 2013). These trends have strongly influenced the ways of production, trade and distribution of food products in the past decade. Governments respond to these changes through new and revised regulations regarding food safety and animal and plant health, relying on resources provided by international organizations such as the World Organization for Animal Health (OIE) and the Codex Alimentarius (Trienekens & Zuurbier, 2008). In this context traceability plays an important role, because the extent to which traceability practices are required by law differs between countries. For example, food businesses located in the EU need to comply with the "European General Food Law" (EGFL) (European Commission, 2002). EGFL defines traceability as "*the ability to trace and follow a food, feed, food-producing animal or substance through all stages of production and distribution*". However, EGFL does not prescribe specific methods for the required keeping and accessing of records (Canavari, Centonze, Hingley, & Spadoni, 2010).

This provides businesses with the opportunity to tailor traceability systems toward their needs and resources (Folinas, Manikas, & Manos, 2006) which has lead to multiple traceability guidelines and standards currently evolving (Karlsen, Dreyer, Olsen, & Elvevoll, 2013). Quite in line with this situation, consensus on a definition of traceability does not exist either (Olsen & Borit, 2013). Hence, traceability capacity varies greatly among operators depending on the business activity, stage in the supply chain and applicable legislation (ECR EUROPE, 2004). A firm's traceability capacity may be described on three dimensions (Golan et al., 2004). First, precision reflects the size of a traceable lot or batch that is uniquely identified. It can range from a single product package to a whole day of production or more. This dimension is also referred to as granularity (Karlsen et al., 2013) and seen as key to traceability performance (Bosona & Gebresenbet, 2013). Second, breadth describes the amount of information collected that can be connected with the lot. Third, depth describes how far back or forward the system regularly traces the relevant information. According to the EGFL as the centerpiece of EU food legislation the minimum legal requirement is "… *one step forward and one step backward*" of the business relationship, while whole chain traceability spans the entire supply chain.

Investing in traceability is capital and resource intense, as it involves reviewing and changing established processes, training of workers and staff and implementation of information technology and other equipment and expertise (Bosona & Gebresenbet, 2013;

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Wang, Li, O'brien, & Li, 2010). Amongst others, costs of traceability depend on the regulatory environment, firm size, firm strategy and culture, technology adopted, characteristics of products and production processes, structure and complexity of the supply chain and the amount of information required to be stored (Food Standard Agency, 2002). We follow Sparling and Sterling (2004) and Chryssochoidis, Karagiannaki, Pramatari, and Kehagia (2009) in differentiating between up-front implementation and on-going operating costs (Table 1). Also following these two author teams, we distinguish between four groups of traceability benefits (Table 2): regulatory, recall and risk management, market and customer response and supply chain operations.

To date, a number of studies have addressed the measurement of costs and benefits of improved traceability (Asioli, Boecker, & Canavari, 2011; Can-Trace, 2007; Donnelly et al., 2013; Hurburgh, 2003; Mai, Bogason, Arason, Árnason, & Matthíasson, 2010; Mejia et al., 2010; Shamsuzzoha, Ehrs, Addo-Tenkorang, Nguyen, & Helo, 2013; Wilson, Henry, & Dahl, 2008). However, few empirical studies have investigated the determinants of different levels of traceability capacity at firm level (Bulut & Lawrence, 2007), firms' incentives for implementing tracking and tracing technologies (Hobbs, Bailey, Dickinson, & Haghiri, 2005), or the performance of traceability systems (Mgonja, Luning, & Van der Vorst, 2013). While it is rather straightforward to assess costs, many benefits are difficult to assess due to low probability of adverse events, difficulty in isolating them from other causes or due to their intangible nature. This is one reason why adoption of traceability has been slow in the food sector (Verdenius, 2006). Still, few analyses of benefits at the firm level are available, although Dabbene, Gay, and Tortia (2013) argue that the definition and evaluation of the performance of a traceability system is a necessary first step in developing traceability-oriented management policies. Furthermore, empirical evidence from expert workshops and case studies suggests enterprises might underestimate the potential benefits of tracking and tracing systems (Fritz & Schiefer, 2009). Similarly, neither should discrepancies between expected and actual costs be ignored (Karlsen et al., 2013). However, the issue of investment under uncertainty, has so far received little attention in the literature on the cost and benefits of traceability. Thus, this paper aims at contributing to closing this knowledge gap through an empirical analysis to provide answers to two specific questions:

a) How do firm characteristics and traceability capacity, as measured by precision, depth and breadth impact costs and benefits of traceability?
b) Are there significant discrepancies between expected and actual costs and benefits, and if so, in which areas are they particularly pronounced?

In the following section, we present the conceptual and empirical model to address these two questions. Section three describes data collection through a survey among Italian fish processing businesses. The fisheries industry is characterized by regulatory requirements for traceability beyond EGFL (2002) but also implementation and enforcement problems. Chiesa et al. (2011) stated the need to develop a new tool for seafood safety and traceability in the Italian clam supply chain. Despite industry specific rules, e.g. EC Regulation No. 104/2000 regulating labeling, quality control and traceability, prevalence of fraudulent mislabeling in which lower value species were sold as higher value species is reportedly high (Garcia-Vazquez et al., 2010; Jacquet & Pauly, 2008). Results are reported in the fourth section, and concluding remarks presented in the fifth section.

Table 1
Categories of traceability costs.

CATEGORY	IMPLEMENTATION	OPERATION/ MAINTENANCE
Time and effort (of workforce, administration and management)	Information search/ processing Change management Test runs/interruptions	Slow down/ interruption of operations Additional reporting/mock recalls
Equipment and software	New purchases/ installation	Upgrades and service contracts
Training	Extensive, comprehensive	Ongoing, for new staff
External consultants	For system choice/ design Comply new hygiene, labeling legislation (veterinary)	For specific challenges Upgrades hygiene, labeling legislation
Materials	Switch to new materials "system"	Labels/Packaging
Certifications and audits	Initial audits/ certification	Repeat audits/ certification

Source: adapted and expanded from Bosona and Gebresenbet (2013), Chryssochoidis et al. (2009), Meuwissen, Velthuis, Hogeveen, & Huirne, (2003), Mora & Menozzi (2003).

2. Conceptual and empirical model

With our conceptual model we propose that a firm's resources and objectives, as summarized by the firm characteristics, determine which level of traceability capacity is optimal or adequate. A chosen capacity level of traceability is then associated with expected costs and benefits (Golan et al., 2003). However, as any investment takes place under uncertainty, the actual outcomes in costs and benefits may deviate from expectations. This implies a two-period optimization problem, in which the investment in a certain level of traceability capacity takes place in the first period and the returns on that investment, as the surplus of benefits over cost, are reaped in the second period. Backward induction would allow determining the optimal level of traceability that would maximize profits, i.e. the surplus of discounted future streams of benefits over discounted future streams of costs net of the implementation cost in the first period. Ex ante, expected costs and benefits are a function of the chosen level of traceability capacity, which in turn is a function of the firm's resources and objectives, summarized under firm characteristics. Costs and benefits of traceability would thus be directly influenced by the level of traceability and indirectly through firm characteristics. While the theoretical analysis is straightforward, a number of challenges arise in the empirical analysis based on cross-sectional survey data, as proposed for this study:

- At the time of measurement, the firm characteristics at the time of the investment decision may not be observable any more or only with reduced accuracy.
- At the time of measurement, expected costs and benefits at the time of the investment decision may not be observable any more or only with reduced accuracy.
- The original level of traceability capacity may not be observable any more, as it might have been adjusted in response to changes in the business environment.

Due to these challenges, the analysis will focus on the actual costs and benefits, as reported for the current firm characteristics and levels of traceability capacity for which survey should provide considerably more accurate representations than for firm

Table 2
Main categories of traceability benefits.

CATEGORY	DESCRIPTION/EXAMPLES
Regulatory	Avoiding penalties for non-compliance No legal barriers to market access Save problems with public authorities
Recall and risk management	More targeted, quicker recall reduces cost Reduced cost of liability insurance Reduce the amount of product destroyed in response to a food safety problem Reduce short-term damages: (e.g. logistic costs of recalls, reduced turnover due to out-of-stock items, costs of laboratory analyses, crisis of communication with retailers and consumers, liability claims and improvements in internal processes, etc.) Reduce long-term damages: (e.g. costs of corporate image, firm reputation and brand value, costs of product re-launches and intensified marketing, etc.) Access to more accurate and timely information needed to make better decisions in relation to how and what to produce
Market and customer response	Reputation (build-up or regain after crisis) New customers and easier market access Real-time information for sales calls Increased demand/price for output Reduce costs of maintaining consumer and market confidence Increasing consumer trust Product differentiation based on credence attributes (e.g. organic food) Pre-condition to enter in international markets Reduce information costs aimed towards consumers associated with quality verification
Supply chain operations	Reduce transaction costs Improved inventory management More efficient communication with customers and/or suppliers Eliminate inefficient practices without value to consumers Improve logistics performances and quality communications among stakeholders Increase company coordination in supply chain Reduces product waste Ensuring a more consistent quality delivery to supply chain end users

Source: Synthesis from Bosona and Gebresenbet (2013); Chryssochoidis et al. (2009); Donnelly et al. (2013); Gellynck, X., Januszewska, R., Verbeke, W. and Viaene, J. (2007); Golan, Krissoff, & Kuchler (2004); Kher, S. V., Frewer, L. J., De Jonge, J., Wentholt, M., Howell Davies, O., Luijckx, N. B. L. and Cnossen, H. J. (2010); Mai et al. (2010); Sparling and Sterling (2004).

characteristics, traceability levels and cost and benefit expectations in the past. The simplified conceptual model thus proposes that actual costs and benefits are a function of the current firm characteristics and levels of traceability capacity.

$$\text{Cost}_{\text{trace implement}} = f(\text{firm characteristics; precision; breadth; depth}) \quad (1)$$

$$\text{Cost}_{\text{trace maintain}} = f(\text{firm characteristics; precision; breadth; depth}) \quad (2)$$

$$\text{Benefit}_{\text{trace}} = f(\text{firm characteristics; precision; breadth; depth}) \quad (3)$$

For the empirical estimation we specify a linear ordinary least squares (OLS) regression model for the dependent cost and benefit variables and the independent, i.e. explanatory firm characteristics and traceability capacity variables:

$$\text{Cost}_{\text{trace implement},\, i} = \alpha_0 + \alpha_1 Q_i + \alpha_2 P_i + \alpha_3 B_i + \alpha_4 D_i + e_{i,\,\text{Cti}} \quad (4)$$

$$\text{Cost}_{\text{trace maintain},\, i} = \beta_0 + \beta_1 Q_i + \beta_2 P_i + \beta_3 B_i + \beta_4 D_i + e_{i,\,\text{Ctm}} \quad (5)$$

$$\text{Benefit}_{\text{trace},\, i} = \gamma_0 + \gamma_1 Q_i + \gamma_2 P_i + \gamma_3 B_i + \gamma_4 D_i + e_{i,\,\text{Bt}} \quad (6)$$

In all equations α_0, β_0, γ_0 stand for the constants, α_1, β_1, γ_1 for a vector of regression coefficients for the characteristics Q_i of firm i, α_2, β_2, γ_2 for the coefficients of traceability precision P_i, α_3, β_3, γ_3 for the coefficients of traceability breadth B_i, and α_4, β_4, γ_4 for the coefficients of the traceability depth D_i, while the e_i–s represent the error term of the estimations. The regression model aims to maximize the proportion of the variance of the dependent variable's scores that is explained by the variation in the independent variables' scores. Significant regression coefficients indicate how much and in which direction an incremental change in the independent variable score changes the dependent variable score, assuming an additive linear relationship.[1] Regression analysis is thus an appropriate tool for answering the first research question that drives this analysis.

The estimation will assess how costs and benefits of traceability are affected by the observed traceability capacity variables precision, breadth and depth, while controlling for firm characteristics. Since traceability capacity levels are dependent on past firm characteristics which also determine current characteristics, collinearity might be present between the three traceability capacity variables and firm characteristics in the estimation. Although Bulut and Lawrence (2007) have not found a strong relation between traceability depth and plant characteristics, a multicollinearity analysis will be performed with the regression analysis.

The second research question, regarding discrepancies between expected and actual costs and benefits will be investigated in a descriptive way only. As discussed at the beginning of this section, it is reasonable to assume that the accuracy of past expectations reported in the survey may be reduced or biased. We therefore refrain from using expected costs and benefits as dependent variables in a regression analysis and report the distribution of discrepancies instead.

3. Materials and methods: data collection, processing and coding

Data were collected through a questionnaire that was pre-tested in spring 2008. The phone survey was administered among Italian fish processors in summer 2008. The sample frame was produced by cross-checking the entire population of fish processors listed in the most recent Italian Census of Industry and Service of ISTAT (2001),[2] and a list provided in the Yearbook of Fishery and Fishing (2007/2008, n.18).[3] The overall population was composed of 415 firms, of which 303 were contacted and 60 responded,

[1] Interpretation of the constant is less straightforward. In the context of this analysis, the constant can be interpreted as a base level of costs (or benefits) that is observed, on average, at the lowest scores of all independent variables.

[2] Istat, 2001. Website: http://dwcis.istat.it/cis/index.htm.

[3] The Yearbook is published by Edizioni Pubblicità Italia s.r.l. (http://www.pubblicitaitalia.com) that is largely considered by the Italian fishery operators as the most important professional Italian publishing house in the fishery supply chain.

yielding an effective response rate of 20%. Although data for assessing the representativeness of the sample is not available, it is reasonable to assume that it is biased towards larger firms. This is due to the fact that the Italian fish processing industry mainly consists of very small, locally operating firms whose manager-owners tend to be reluctant to participate in surveys.

The following Tables 3–5 present how the variables that enter the analysis to represent firm characteristics, traceability capacity indicators and cost and benefit indicators were measured and recoded into indices.[4] The firm characteristics variables in Table 3 are reflective of strategy components that are hypothesized to affect costs and benefits of traceability. E.g., the number of regions from which a company sources its raw materials (SOURCE), as well as the number of sales destination regions (DESTIN) can be expected to be positively related with the cost of traceability. Similarly, as the number of quality management or safety assurance standards for which a firm has obtained certification increases, the likelihood of conflicting traceability requirements increases. The hypothesized consequences would be increased costs and reduced benefits of traceability. Given the multifaceted and dynamic nature of operations and of relationships with suppliers and customers, it has to be acknowledged that the indicators of firm characteristics presented in Table 3 are only approximations of the true state of each firm.

The ways in which the three traceability capacity dimensions precision, breadth and depth were constructed based on responses to survey questions are documented in Table 4. The questions and answer categories provided to respondents were based on a literature review and an in-depth case study previously conducted by one of the authors. Quite obviously, what constitutes the breadth of traceability is industry-specific and can be specified in considerably more detail than was done in this study, if the research focus is on particular product attributes. A major challenge for the measurement of breadth and precision is that the requirements may vary across customers.

Costs and benefits at the overall level were measured using 9-point rating scales as described in Table 5. Since the overall cost and benefit categories were each comprised of various specific costs and benefits as shown in Tables 1 and 2. Both costs and benefits include components that are intangible and can be perceived in different ways. For example, increased consumer trust and a more targeted recall are both important benefits but difficult to assess in an objective way, if a recall event has not occurred after implementation of the traceability system. Similarly, change management is an important part of traceability implementation costs that is difficult to quantify in monetary value, unless extensive record keeping of time spent on training, on negotiations to overcome workforce opposition to change and on information search to find solutions is maintained – which typically is not the case. Hence, attempting to measure costs and benefits in monetary value was not feasible. Instead, we used the firm's annual sales as an anchor point for the respondents against which to assess costs and benefits on a rating scale from 1 (very small) to 9 (very large) in order to reduce the subjective component in the assessment. This has to be kept in mind when interpreting the results of the regression analysis.

In addition, specific cost and benefit categories were reported using constant sum scales of one hundred points to reflect percentage shares of specific categories in the overall cost and benefit categories. These measurements will be addressed in more detail when discrepancies are discussed in the descriptive analysis following the regression results.

Table 3
Firm characteristics indicators.

VARIABLE	CODING	SCORES
SIZE	Average score of labor force score (based on full time, part time, seasonal employee numbers reported in 4 size categories) and annual revenue categories (1: below EURO 250,000; 8: above EURO 25 million).	Min score: 1 Max score: 8 Increment: 0.25
VERT-INT	Number of supply chain stages at which respondent firm operates: harvesting, processing, wholesale, retail. Each stage operated at adds a value of 1 to the score.	Min score: 1 Max score: 4 Increment: 1
INPUT	Number of different raw material types that are used in operation: seafood, freshwater fish, shellfish, crustaceous, wild, farmed. Each reported raw material type adds a value of 1 to the score.	Min score: 1 Max score: 7 Increment: 1
SOURCES	Number of different regions from which raw materials are sourced: Italy, other EU countries, other European countries, North America, South America, Africa, Asia. Each reported sourcing region adds a value of 1 to the score.	Min score: 1 Max score: 7 Increment: 1
OUTPUT	Number of different product categories that are produced at facility: fresh, frozen, deep-frozen, preserved/pickled, dried/salted/smoked. Each reported product category adds a value of 1 to the score.	Min score: 1 Max score: 5 Increment: 1
DESTIN	Number of different regions to which output is sold: Italy, other EU countries, other European countries, North America, South America, Africa, Asia. Each reported region adds a value of 1 to the score.	Min score: 1 Max score: 7 Increment: 1
CUSTOMERS	Number of different customer types to which output is sold: International/national retailer; Regional/local retailer; Local fishery shop; Pitchman; Wholesaler; Wholesale market; Food service chain; Other Food service operator; Direct to the final consumer; Other processors; Institution. Each reported customer type adds a value of 1 to the score.	Min score: 1 Max score: 11 Increment: 1
QMS	Number of food quality or safety assurance/management standard to which the firm is certified (Each reported certification adds a value of 1 to the score): - ISO 9001:2000: guides in consistent documentation of production steps, supports traceability; - HACCP: Hazard Analysis Critical Control Points, has elements of traceability; - ISO22000:2005; guides in traceability practices; at time of study newly introduced, with very few certifications then; - MSC: Marine Stewardship Council, limited traceability requirements. - ISO14001:guides in documentation of sustainable practices, supports traceability; - IFS: International Food Standard, limited traceability requirements; - BRC: British Retail Consortium; requires traceability to varying degrees, - EUREPGAP: Standard used by retailers, originated in fresh produce production and handling practices, extended to seafood, limited traceability requirements.	Min score: 0 Max score: 8 Increment: 1

(continued on next page)

[4] A copy of the questionnaire is available from the authors upon request.

Table 3 (*continued*)

VARIABLE	CODING	SCORES
GOV-SUPPORT	Has a government (EU, National, Regional, Provincial or Municipality) or a Government Agency been or is involved in supporting the implementation of the traceability system? (yes = 1; No = 0)	Min score: 0 Max score: 1 Increment: 1
REGION-NORD	Depending on location in an Italian province, a respondent firm was assigned to one of the larger regions North, Central or South. A score of 1 was assigned to respondents in the North, 0 to the location being in any other province.	Min score: 0 Max score: 1 Increment: 1

4. Results and discussions

4.1. Sample description

Turning to the sample descriptive statistics, 42% of respondents reported operating revenues above 10 million EUROS in 2007. Further, 57% of the firms were located in the North of Italy. 18% were active at the harvesting stage of the supply chain, 73% at the processing stage, 38% at wholesale, 30% at retail; in total 47% were active at more than one supply chain stage.

With regard to the complexity of the inputs, as measured by the number of raw material types and sourcing regions, 55% used three or more raw material types, while 58% sourced from four or more regions, with Italy (85%), other EU countries (73%) and Asia (55%) being the three sources stated most often. On the output side, 60% produced three or more product types, while 58% had two or more destination regions for sales, with Italy (100%), other EU countries (55%) and other European countries (15%) being mentioned most often.

Wholesalers (83%), international/national retail chains (77%) and local fish shops (60%) were the customer types most often served. Documenting a diversified customer structure overall, 45% of the sample had seven or more different customer types. With regard to certified quality management systems, 57% of the firms in the sample were certified according to two or more standards. HACCP (88%), ISO 9000:2001 (42%) and the International Food Standard IFS (25%) were reported most often. Finally, nine firms (15%) reported to have received government support for the implementation of a traceability system.

Next, Table 6 provides a descriptive overview of the three traceability capacity indicators. While the average score for the breadth index is located close to the midpoint of the scale (12), the average score for the precision indicator is located considerably closer to the maximum of the scale (8). A bit surprisingly high, 40% of the respondents indicated that they were able to both trace and track beyond the one-up, one-down minimum legal requirement on a regular basis.

As shown in Table 7, the descriptive statistics for the cost and benefit indicators show a considerable degree of variation for the expected and actual outcomes as well as for the discrepancies between them, as documented by the relatively large standard deviations. The average scores are located close to the scale midpoints though. While actual implementation costs were lower than expected, operating costs were rated, on average, slightly higher than expected. On average, benefit expectations were not met either.

4.2. Determinants of costs and benefits

When turning to the regression results, it has to be noted the variable SOURCE was dropped from the list of independent variables due to multicollinearity issues. For the regressions with the remaining independent variables, the adjusted R^2 and significance (p) of the F value are found to be low for implementation and operating costs (Table 8). This poor data fit does not lend support for the hypothesis that traceability costs are influenced by firm characteristics and traceability capacity, even though BREADTH is significant at the five per cent level for both regressions. Its coefficient sign and magnitude indicates that the implementation and operating cost scores increase by 0.212 and 0.200 units respectively when the BREADTH score increases by one. Given that costs were rated relative to firm size (annual sales) this result means that the absolute costs were perceived to increase with firm size.

For overall benefits, however, model fit is considerably better and significant at the 5 per cent level. Here, PRECISION of traceability is driving the benefits. As its score goes up by one unit, the benefit score increases by slightly over half a unit. As with costs, benefits were measured relative to firm size. In this case, benefits can then also be assumed to increase in absolute terms, as firm size increases. The same applies to BREADTH, although to a considerably smaller extent due to the smaller regression coefficient.

Table 4
Variables indicating the level of traceability capacity.

Index	QUESTION	CODING	SCORES
BREADTH	What information is recorded for an individual input batch? And which of these are regularly linked with an output unit?	One (1) score for each of the 12 types of information at input and output stage each: “Supplier details”; “Data and hour of product arrival”; “Date of harvest”; “Location of harvesting/farming”; “Water quality classification”; “Method of production”; “Scientific name of the species”; “Commercial name of the species”; “Quantity”; “Quality grading”; “Other1”; “Other2”.	Min score: 0 Max score: 24 Increment: 1
PRECISION	What are the smallest units that your company can trace at the input and output levels?	Sum of the scores for precision indicator at input and output stage each: *“Two or more days of production”* (score = 1); *“One day of production”* (score = 2);“ *Input from individual supplier/buyer”* (score = 3); *“Multiple batches from one supplier/buyer”* (score = 4).	Min score: 2 Max score: 8 Increment: 1
DEPTH	Are you able to trace (track) your inputs (products) beyond the direct suppliers of inputs (customers) on a regular basis?	Firm is able to regularly trace its input beyond the direct suppliers and to track its output beyond the direct customer (one step down)” (score = 1); Recoded variable from two original questions addressing tracing (backward) and tracking (forward) separately.	Min score: 0 Max score: 1 Increment: 1

Table 5
Indicators of expected and actual cost and benefits and discrepancies.

INDEX	EXPLANATION	RESPONSE SCALE	RANGE OF SCORES
EXPECTED COST OF IMPLEMENTATION	Expected implementation costs, relative to firm size (sales)	Rating scale: from 1 (*Very low*) to 9 (*Very high*)	Min score: 1 Max score: 9
ACTUAL COST OF IMPLEMENTATION	Actual implementation costs, relative to firm size (sales)	Rating scale: *from 1 (Very low) to 9 (Very high)*	Min score: 1 Max score: 9
IMPLEMENTATION COST DISCREPANCY	Discrepancy between expected and actual implementation costs	Actual implementation cost − Expected implementation cost	Min score: −8 Max score: +8
EXPECTED OPERATING COSTS	Expected operating costs, relative to firm size (sales)	Rating scale: *from 1 (Very low) to 9 (Very high)*	Min score: 1 Max score: 9
ACTUAL OPERATING COSTS	Actual operating costs, relative to firm size (sales)	Rating scale: from 1 (*Very low*) to 9 (*Very high*)	Min score: 1 Max score: 9
OPERATING COSTS DISCREPANCY	Discrepancy between expected and actual operation costs	Actual operating cost − expected operating cost	Min score: −8 Max score: +8
EXPECTED BENEFITS	Expected overall benefits, relative to firm size (sales)	Rating scale: from 1 (*Very low*) to 9 (*Very high*)	Min score: 1 Max score: 9
ACTUAL BENEFITS	Actual overall benefits, relative to firm size (sales)	Rating scale: *from 1 (Very low) to 9 (Very high)*	Min score: 1 Max score: 9
BENEFITS DISCREPANCY	Discrepancy between expected and actual benefits	Actual benefits − expected benefits	Min score: −8 Max score: +8

However, the negative sign of the SIZE functions as a partial corrective of that impact. In summary, firm characteristics have not been found to impact traceability costs, while there is some influence of size on benefits. Clearly, the traceability capacity measures have been shown to influence both costs and benefits.

The fact that the estimation did not produce a significant coefficient in all three regressions for seven out of nine firm characteristics supports findings from previous analyses that, once a traceability system is implemented the association between firm characteristics on the one hand and costs and benefits of traceability on the other is weak at best. A plausible explanation might be that each firm's set of customer or market requirements and its operational set-up are so unique that no strong relationship can be observed across cost and benefit categories.

Turning to the indices of traceability capacity levels, the lacking significance of DEPTH may be due to measurement issues. Please recall that a share of 40% of respondents going regularly beyond the one-up/one down requirement for tracking and tracing was surprisingly high. The responses may have included those that understood this as a question about compliance with regulation, i.e. to be able to trace back to the next supplier one-up and to track forward to the direct, one-down customer. Also, a bit surprising, breadth was found to increase both cost categories significantly, although the pre-study and communication with experts pointed to precision as more directly related with cost, because of the larger interference of precision requirements with the flow of operations. However, both BREADTH and PRECISION were found to be significantly and positively related with the overall benefits of the implemented traceability system. Hence, it appears that the PRECISION a traceability system can afford is the key driver of traceability benefits.

4.3. Discrepancies between expected and actual costs, and benefits

Reflecting on the uncertainty of investing in traceability, Table 9 shows the distribution of discrepancies between expected and actual outcomes for implementation and operating costs, as well as for overall benefits. No discrepancy between expected and actual outcomes was reported by 19 (33%) and 25 (44%) respondents, respectively. For the cost indicators, a negative discrepancy indicates that the actual cost were smaller than expected. Such a "positive surprise" was experienced by roughly the same number of firms as was the "negative" counterpart when actual costs exceeded the expected costs. The only difference that can be found between implementation and operating cost is that larger positive surprises were less likely for operating costs.

Contrary to expectations based on findings presented in the literature review, there is no evidence that actual benefits deviate in a more pronounced way from expectations than costs do. However, for benefits the distribution is a bit out of balance, as 20 firms experienced a "negative surprise", that is, expectations exceeded actual benefits, while only 12 realized larger benefits than expected. This finding contrasts with the anecdotal evidence reported by Fritz and Schiefer (2009) that many firms tend to underestimate the benefits from traceability.

Finally, the survey also included a section in which respondents were asked to distribute 100 points across five specific categories of implementation costs and also 100 points across seven specific benefit categories both for expected and actual outcomes. The discrepancies were calculated in the same way as for the super ordinate cost and benefit categories, i.e. by subtracting the expected outcomes from the actual outcomes. Again, the variation in discrepancies among respondents was considerable, but covered positive and negative surprises as discussed above fairly evenly, so that the averages across the entire sample did not deviate greatly from zero. However, two specific categories deviated by more than

Table 6
Descriptive statistics of the level of traceability indicators.

INDICATOR	Mean	Standard deviation	Min.	Max.
BREADTH	12.93	4.30	2	24
PRECISION	6.28	1.80	2	8
DEPTH (Share)	0.40	0.49	0	1

Table 7
Descriptive statistics of cost and benefit indicators.

INDEX	*N*	SCALE		MEAN	SD	MIN	MAX
Expected implementation cost	57	1	9	5.81	1.97	1	9
Actual implementation cost	57	1	9	5.41	2.58	1	9
Discrepancy implementation cost	57	−8	+8	−0.39	2.33	−8	4
Expected operating cost	56	1	9	5.03	2.18	1	9
Actual operating cost	56	1	9	5.23	2.46	1	9
Discrepancy operating cost	56	−8	+8	0.20	1.72	−3	5
Expected benefits	57	1	9	6.67	2.01	1	9
Actual benefits	57	1	9	6.32	2.07	1	9
Discrepancies benefits	57	−8	+8	−0.35	1.80	−7	5

Table 8
Regression results for perceived actual cost and benefit indicators.[a]

	Implementation cost	Operating cost	Overall benefits
R2 adjusted	0.089	0.056	0.267
F-value (*p*)	1.45 (*0.18*)	1.27 (*0.25*)	2.70 (*0.01*)
Coefficients			
CONSTANT	2.586	2.850	2.578
SIZE	−0.402	−0.282	−0.665***
QMS	0.585*	0.452	0.144
BREADTH	0.212**	0.200**	0.132**
PRECISION	0.084	0.071	0.603***
DEPTH	0.569	0.440	0.609

*, **, *** indicate significance levels for regression coefficients of 10%, 5% and 1% respectively.

[a] Variables VERT-INT, INPUT, OUTPUT, DESTIN, CUSTOMERS, REGION-NORD, and GOV-SUPPORT were also entered into regression analysis but did not yield significant results at the 10% significance level. Hence, their coefficients are not reported. Variable SOURCES was omitted due to multicollinearity issues.

Table 9
Distributions of discrepancies between expected and actual outcomes.[a]

Discrepancy	−4 to −8	−2 to −3	−1	0	1	2 to 3	4 to 8
Implement. cost	3	13	4	19	6	11	1
Operating cost	–	2	16	21	5	9	3
Overall benefit	2	8	10	25	6	5	1

[a] Discrepancies are calculated by subtracting the expected outcome from the actual outcome.

two points from zero, in both cases indicating a tendency toward a "negative surprise".

On the implementation cost side it was the need for Production line, supervisory staff and managerial/administrative time that was underestimated, while expectations about Increasing market share or accessing new markets or obtaining a price premium had been overly optimistic on the benefit side. The histogram for this benefit category demonstrates that this discrepancy is mainly driven by four respondents that apparently had greatly overestimated this benefit (Fig. 1). While the small number of firms affected by this large discrepancy may not give rise to concerns, the extent of this negative discrepancy does, as it might easily translate into massive disappointment that may be communicated quickly among peers.

5. Concluding remarks

In this paper we focused on the Italian fishery processors, using a relatively small sample of fish processing companies. We acknowledge that mid-large size firms are overrepresented in the sample; therefore we cannot generalize our findings to the Italian fishery processors as a whole. However, the analysis provides useful information for both managers and policy makers.

The proposed decision model shows that breadth and precision may influence actual costs and benefits in different ways. First, an increasing precision increases benefits while it does not affect costs – at least in the respondents' experience that served as the basis for their responses. The finding that precision does not affect costs is actually in contrast with our prior communication with industry experts, who hypothesized precision as being directly related with cost. Second, an increasing breadth of information provided with traceability apparently increases the complexity of the established traceability system and, with it, the implementation and maintenance costs. This is supported by the observation that an increasing number of certifications according to quality management and assurance standards, such as HACCP or ISO9000, likewise increases the complexity of requirements and thus the cost of implementation. Moreover, it is noteworthy that firm characteristics were found to be only weakly linked with costs and benefits. This observation may caution any attempts to develop templates for traceability solutions that are intended to be applied in a "One size fits all" manner, because the uniqueness of each firm's sets of resources, objectives and technologies calls for customized traceability solutions.

In addition to the comprehensive analysis of the relationships between costs and benefits of traceability, firm characteristics and the capacity levels of traceability this paper addressed an issue that has so far received little attention in the empirical literature, as also highlighted by Karlsen, Dreyer, Olsen, and Elvevoll (2012). As the concluding descriptive analysis has shown, the uncertainty around costs and benefits of investments in traceability has produced considerable discrepancies between expectations and actual outcomes. Using the benefit category with the most extreme discrepancy, that is "*Increasing market share or accessing new markets or obtaining a price premium*", massive negative surprises were reported by a small number of respondents. This may have impacts on the communication about traceability among peers and thus on the future uptake of further advancing traceability technologies and activities.

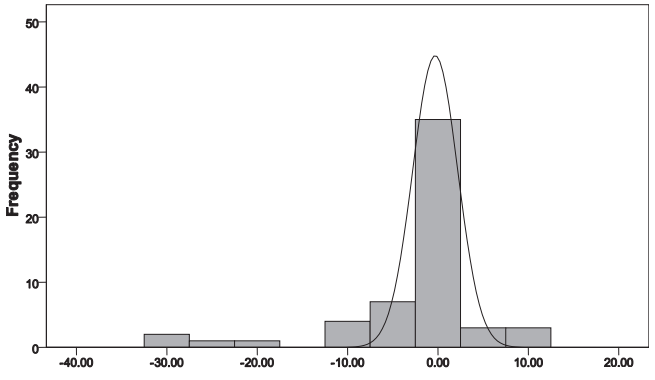

Fig. 1. Distributions of discrepancies for market share and price premium benefit.[a]

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