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INNOVATION IN AQUACULTURE. MODELING THE ADOPTION AND IMPLEMENTATION PROCESSES OF INNOVATIONS IN THE ITALIAN AQUACULTURE SECTOR

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Innovation in aquaculture. Modeling the adoption and implementation processes of innovations in the Italian aquaculture sector

Abstract

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Since the turn of the century, fisheries have maintained a steady growth rate, while aquaculture has experienced a more rapid expansion. Aquaculture can offer EU consumers more diverse, healthy, and sustainable food options, some of which are more popular elsewhere. To develop the sector, the EU is investing heavily. The EU supports innovative projects that promote the sustainable development of seafood sectors and food security. Priority 3 promotes sector development through innovation dissemination. This doctoral dissertation examined innovation transfer in the Italian aquaculture sector, specifically the adoption of innovative tools, using a theoretical model to better understand the complexity of these processes. The work focused on innovation adoption, emphasising that it is the end of a well-defined process. The Awareness Knowledge Adoption Implementation Effectiveness (AKAIE) model was created to better analyse post-adoption phases and evaluate technology adoption implementation and impact. To identify AKAIE drivers and barriers, aquaculture actors were consulted. "Perceived complexity"—barriers to adoption that are strongly influenced by contextual factors—has been used to examine their perspectives (i.e. socio-economic, institutional, cultural ones). The new model will contextualise the sequence based on technologies, entrepreneur traits, corporate and institutional contexts, and complexity perception, the sequence's central node. Technology adoption can also be studied by examining complexity perceptions along the AKAIE sequence. This study proposes a new model to evaluate the diffusion of a given technology, offering the policy maker the possibility to be able to act promptly across the process. The development of responsible policies for evaluating the effectiveness of innovation is more necessary than ever, especially to orient strategies and interventions in the face of major scenarios of change.

INNOVATIVE TECHNOLOGIES AND SUSTAINABLE USE OF FISHERIES AND BIOLOGICAL RESOURCES IN THE MEDITERRANEAN SEA (FISHMED-PHD)

Multi-year research project proposal in

Innovation in aquaculture. Modeling the adoption and implementation processes of innovations in the Italian aquaculture sector

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Summary

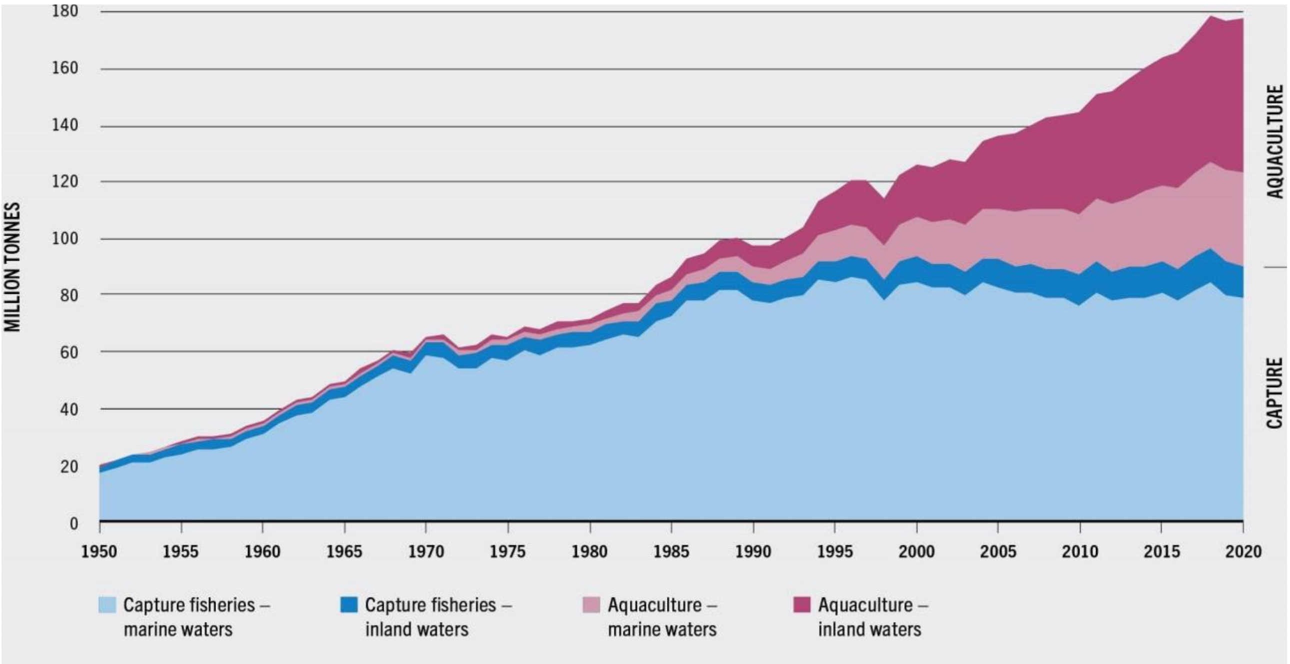
Introduction

State of the art

In the twenty-first century, the fisheries and aquaculture sectors are increasingly acknowledged for their indispensable contribution to global food security and nutrition (Kobayashi et al., 2015). To attain sustainable and equitable global fisheries and aquaculture, further expansion of this contribution necessitates rapid transformations in policy, management, innovation, and investment.

In the last decade, fisheries have shown a steady trend, while aquaculture has undergone a more rapid expansion (Eurostat, 2018). According to the FAO report "The State of World Fisheries and Aquaculture" (2022), the predicted global output of aquatic animals in 2020 is 178 million tonnes, a little decline from the record-breaking 179 million tonnes produced in 2018 (Figure 1). Over 157 million tonnes (89 percent) of the total production of aquatic animals were consumed for human food. The remaining 20 million tonnes were intended for non-food applications, mostly for the production of fishmeal and fish oil (16 million tonnes or 81 percent).

Fig. 1 - World Capture Fisheries and Aquaculture Production



Source: SOFIA 2022

Capture fisheries produced 51 percent, or 90 million tonnes, while aquaculture contributed 88 million tonnes (49 percent). 63 percent (112 million tonnes) of the entire production was gathered in coastal waters (70 percent from capture fisheries and 30 percent from aquaculture), while 37 percent (66 million tonnes) was harvested in inland waterways (83 percent from aquaculture and 17 percent from capture fisheries). The initial selling value of the global production was anticipated to be 406 billion dollars, with capture fisheries accounting for 141 billion dollars and aquaculture for 266 billion dollars. In 2020, in addition to aquatic animals, 36 million tonnes (wet weight) of algae were generated, of which 97% derived from aquaculture, primarily marine aquaculture.

According to the data published by Eurostat, in 2018 only 25 % of the average total consumption of fish and shellfish in the EU came from aquaculture and even fewer comforting data come from the production side, in fact the EU accounts for less than 2 % of world production and just 10 % of fish products consumed within the EU itself. Moreover, production is almost completely concentrated in four states (Spain, France, Italy and Greece), which account for around 70 % of production. The sector therefore still has wide margins for expansion. According to estimates collected by Eurostat, there are around 15,000 companies in the EU operating in the aquaculture sector, most of them micro-enterprises with less than 10 employees. In total, the sector employs almost 70 000 people (2018 data). According to data from the Italian Fish Farmers' Association (2022), in 2021, the Italian fish farming sector had a turnover of almost 300 million euro, producing 62,150 tonnes of fish of twenty different species, distributed in more than six hundred production sites. The record is held by trout farming, which, with 37,000 tonnes, reached a value of 115,500,000 euro, followed by sea bream and sea bass, with more than 17,000 tonnes, equal to 141,900,000 euro. Consequently, there is still considerable potential for growth and diversification in terms of both producing countries and farmed species. Moreover, aquaculture can provide EU consumers with even more varied healthy and sustainable food products, some of which are more widely consumed in other regions of the world. To this end, the European Union is investing heavily in the development of the sector, in fact recently, the European Commission adopted the Communication Strategic Guidelines for a more sustainable and competitive European aquaculture for the period 2021-2030. The document is part of the Farm to Fork strategy, which identified aquaculture as a potential driver for food sustainability as a source of low-carbon food and feed. Although the strategy aims to develop the sector, it still fails to establish itself in the EU as a driver for the development of the fisheries sector. This documentation, following the seven-year planning 2021-2027, delivered to us by the new European Maritime, Fisheries and Aquaculture Fund (EMFAF), entered into force on 14 July 2021, supporting the EU common fisheries policy (CFP), the EU maritime policy and the EU agenda for international ocean governance. The total budget for 2021-2027 is €6.108 billion.

Among the various objectives of the CFP, we find ensuring food security through the supply of seafood products and developing a sustainable blue economy, through the support of innovative projects that contribute to the sustainable exploitation of the sector. For this purpose, the dissemination of innovations is identified as a way to develop the sector, e.g. priority 3 ("Enabling the growth of a sustainable blue economy and promoting the prosperity of coastal communities") focuses particularly on the adoption of technological innovations. The priority finds justification in the literature, in fact one of the weaknesses of the fisheries and aquaculture sectors is the low propensity of operators to change and introduce innovations (Kumar et al., 2018). One of the most frequent reasons is the economic sustainability of the introduction of innovations. The COVID-19 pandemic has severely affected the European aquaculture sector (Vecchio et al 2022), and the Russian-Ukrainian war has worsened the situation, causing increases in energy and transport costs, undermining the already fragile economic viability of companies in the sector. The scenario is therefore that of a new crisis for the sector, which may find it difficult to follow European strategies for the ecological transition and the introduction of new technological innovations.

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Project

The aim of this doctoral project was to analyse in depth the topic of innovation transfer in the aquaculture sector in Italy, in particular by investigating the adoption of innovative tools through a theoretical model that allows us to better identify the complexity that such processes generate.

The work was structured around the concept of adoption of an innovation, highlighting how this stage is only the result of an articulated process. It was possible to explore this complex process from the AKAP model (Evenson 1997). The sequence awareness-knowledge-adoption-productivity (AKAP), defines the natural order of the stages leading to the adoption of the innovation, including impact of adoption. Within the AKAP sequence, individual and collective resources are mobilised to promote business innovation processes. The use of this conceptualisation mainly allows one to:

- better understand the characteristics of the adoption process in relation to specific innovations (Evenson 1997);
- helps to identify the “gaps” associated with each stage of the AKAP sequence.

The AKAP approach has been widely used in the literature to explain the impacts of services to agriculture and to innovation transfer (Riawanti and Effendi 2017; Vecchio et al. 2020). Considering the introduction of innovation by farmers as it proceeds through the AKAP sequence can be a useful analysis tool, particularly to help the policy-maker first capture, and then try to fill, the gaps that in a given context are associated with each stage of the sequence. Including the post-adoption phase of the process, the “product”, which refers to the performance induced by the innovation adopted. The few works that have used a different meaning of “product” have focused on changes in agricultural practices, involving various potential innovations (strategic, regulatory, technical, marketing, organisational, managerial, etc.), linking them to the eventual benefits of adoption (De Rosa, Bartoli, La Rocca 2014).

Following this direction, in this work, through various steps, a new model was defined, which rests its foundations on the AKAP approach with the aim of addressing the implementation and effectiveness phase with different metrics from the traditional ones.

This work proposes a revised AKAP model, the so-called Awareness Knowledge Adoption Implementation Effectiveness (AKAIE), to better analyse post adoption phases, in order to evaluate implementation and impact of technology adoption.

In order to deepen different drivers and barriers along the AKAIE sequence, the point of views of various actors of aquaculture sector have been addressed.

Their point of views has been analysed through the lens of "perceived complexity", which could be summarised as the perceived barriers along the adoption process, which degree is strongly influenced by different contextual factors (i.e. socio-economic, institutional, cultural ones).

In order to escavate the different points of view of different actors of the aquaculture sector in Italy, a new methodology was proposed, the Q-Methodology. It mixes qualitative approaches, necessary to capture the multiple faces of subjectivity that escape reduction in numbers, with quantitative techniques that help to measure results.

The project is divided into several chapters in which we will briefly introduce the theories of innovation and some of the models used to try to analyse the innovation transfer process, and then continue with a series of original works.

In the first chapter, starting from the work of Joffre et al. (2018), who states that they find the same behavioural patterns in the adoption processes of innovations by aquaculturists as farmers, a questionnaire was structured using Q-methodology for the agricultural sector where there is more supporting literature. The use of a hybrid methodology for understanding points of view allows us to render in numbers what normally belongs to the cognitive sphere. Starting with agriculture allows us to have more supporting data to later develop the work on the aquaculture sector.

In the second chapter, after analysing the views of experienced operators in agriculture, already users of precision techniques, the views of the aquaculture policy network were analysed. To this end, a new Q-methodology was conducted on the industry's stakeholders, including trade associations, institutions, experts, academics, consultants and ministry managers. The rationale lies in the fact that to fully understand the whole process, and to be able to fully develop a model, it is necessary to understand the point of view of the actors who actually affect the process of creating policies that enable the diffusion of technologies.

Based on the previous chapter that allowed us to capture the views of both policy makers and experienced producers, in the third chapter, once the needs were outlined, it was possible to draw the line for the definition of the new model, the AKAIE. This model has its roots in Evenson's pioneering work of 1997 and his publication on the AKAP model and not only expands on this work, but also reinterprets it in a contextual key, as defined by Welter (2011) who, stating that "*contextualisation is about recognising differences*", seeks to provide a framework for analysing results by focusing on two macro levels, the "who" and the "where". The first defined Who context is represented by sociodemographic variables. From the study of the literature have emerged several aspects to consider, such as age, level of education or gender. In the second variable, the where context, the literature has brought out several elements among which the two most important ones to focus on are certainly the company dimension and the fact that innovation technologies fit the model of a capital-intensive technology: they required high entry costs, large fixed transaction ones and others "hidden costs" such as educational and informational ones. The where dimension is also for the institutional context, including cognitive, cultural, more generally dimensions addressing individual behaviour. This "perceived complexity" dimension may concern either a general propensity to innovation, strictly linked to:

a) The farmer's familiarity with technology (Gow, Oliver, Gow, 2002);

b) Uncertainty about economic results (Pierpaoli et al., 2013; Kumar et al. 2018).

In the new model, therefore, there will not only be a contextualisation of the sequence on the basis of technologies, the characteristics of the entrepreneur and the contexts, both corporate and institutional, but also a focus on the perception of complexity, the central node of the sequence, taking its cue from another work that has defined a holistic approach called the FACOPA model (Vecchio et al. 2022). Studying perceptions of complexity along the AKAIE sequence will also allow the impacts of technology adoption to be investigated.

In the last chapter, we discuss the following question: Can we develop responsible innovation policies? According to the findings, many tools are available but difficult to implement. Solutions to avoid the negative effects of immediate technology dissemination, such as monopolies, are particularly difficult to find. The current state of the art cannot generate a large database for 'prior knowledge' due to poor dissemination or average diffusion with low implementation. As demonstrated in the first paper, examining technology adoption bottlenecks is only the beginning of the potential factors that can support responsible innovation from the perspective of the company to policy actions. All stakeholders must fully incorporate RRI elements into PFs for more responsible policies.

Discussion and conclusion try to summarize the findings of the chapters and provide insights for future research.

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First Chapter

Title page

Precision farming: what do Italian farmers really think? An application of the Q methodology

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Abstract

CONTEXT Precision farming (PF) is a term that is now widespread throughout agricultural systems worldwide. It is studied in many ways, from its strictly technical connotation of a farm management strategy that uses information technology to support decision-making processes to the steppingstones and the dissection of the factors involved in the complex scenario of adopting related tools. Starting from the statement "*In my opinion, precision farming is…*", the present work investigates the perspective of the agricultural entrepreneur in conceptualising PF. Some researchers have highlighted the role of the sphere of the *self* in adoption, but few efforts have been made to better understand the role played by farmers' perceptions in the formation of their thinking about innovative tools.

OBJECTIVE This work aims to deepen the sphere of the self and, in particular, the role played by farmers' perceptions when faced with the innovation adoption choice. The study presents a new conceptual framework identifying key stages for analysing adoption processes, focusing on the relationships between behaviour, structural dimensions and adoption, interpreted from the farmer perspective.

METHODS: The Q methodology (QM) was used with a targeted sample of 23 farmers to identify prevailing discourses. In the first step, the socio-structural dimensions were analysed through descriptive analysis, and in the second step, the discourses were extracted by an intercorrelation matrix through the centroid procedure, translating the solution using varimax rotation.

RESULTS AND CONCLUSIONS This paper highlights that the QM is an appropriate technique for exploring and studying farmers' attitudes when challenged with innovation. The results reveal discourses that summarise three macro perspectives: the "proactive approach", which represents farmers who perceive PF as having a key role for agricultural enterprises; the "conservative approach", which characterises those who distrust innovations; and the "doubtful approach", which is the more sceptical vision.

SIGNIFICANCE This study demonstrates the importance of moving beyond simply quantitative studies that methodically analyse adoption processes and overcoming the constraints of qualitative research by employing a mixed approach to identify the common perspectives of farmers. This analysis can be used by policy makers as a new survey tool to make stakeholder consultations more effective, as the 3 approaches may help to enrich the discourse on PF. The results provide new perspectives to promote responsible policies to support the effectiveness of PF.

Keywords: precision farming, Q methodology, perception, sphere of the self, innovation adoption

1. Introduction

The European Green Deal includes an action plan aimed at promoting the efficient use of resources by moving to a clean and circular economy and aimed at restoring biodiversity and reducing pollution. The European Commission (EC) has developed guidelines to support the achievement of these objectives by "investing in environmentally friendly technologies" and by "supporting industry in innovation" (European Commission, 2019). Precision farming (PF) has the potential to meet the challenges posed by the public ambition to produce more while consuming fewer resources (Stafford, 1996; Ogle et al., 2014; Coluccia et al., 2020). PF has been defined as "a concept of agricultural management based on observation, measurement and response to inter- and intra-field variability in crops or livestock aspects" (European Parliament, 2014, p.11). Not only are European institutions supporting it as a fundamental practice for the development of agricultural sustainability in the future, but they are also focusing on the political need to act to improve farming practices, for which it is necessary to "boost investments and uptake of new technologies and digital-based opportunities such as precision agriculture" (European Parliament, 2016, p. 16). Studies have addressed the crucial role that data management will play in making farmers' work more efficient (Daberkow and McBride, 1998; Finger et al., 2019) through the use of combined technologies (geographic information systems (GISs), remote sensors, smart tractors) and operational focuses (use of fertilisers and pesticides, soil tillage regime, water saving, etc.) (Robertson et al., 2012). In addition to these strictly technical factors, socio-ethical and environmental variables linked to the application of technological innovation (TI), in terms of good or negative impacts on agriculture in the future, should be considered (Lioutas et al., 2021). Today, new responsibilities have been assigned to agri-food systems along with the challenge posed to innovation processes to produce a desired scenario, especially in environmental and socio-ethical terms for the agriculture of the future (Charatsari et al., 2022; Rijswijk et al., 2021). In this sense, the need to boost a more responsible adoption of innovation paths is emphasised within the field of responsible research and innovation (RRI) (Stilgoe et al., 2020; Gremmen et al., 2019). Only a few studies have examined the extent to which RRI principles have been applied to PF (Rose and Chilvers, 2018; Eastwood et al., 2019). In particular, the development of a framework of responsible innovation (RI) in agriculture requires the study of 4 dimensions (Charatsari et al., 2022): anticipation, inclusion, reflexivity, and responsiveness. Anticipation is related to the ability of research and innovation policy to anticipate an unfavourable scenario in terms of potential environmental and socio-ethical risks, while reflexivity has been defined as the promotion of new reflection processes around innovation processes by including all prospective actors to reduce negative impacts while enhancing positive outcomes. Furthermore, the inclusion of stakeholders and bottom-up governance strategies have been proposed as principles for promoting engagement in innovation processes and innovation trust. The last principle, responsiveness, includes the ability to support a change of course within innovation processes once new knowledge, emerging challenges or needs have been discovered.

The RRI literature has risen to prominence in relation to numerous technologies that have high potential but considerable uncertainty. However, applications to precision farming technologies (PFTs) are limited (Bronson, 2019). Analysing the desirability of PF through the RRI lens may be very useful since scholars have highlight the notable difficulty in the transfer and adoption of TI. As a demonstration, many authors have described several barriers to adoption, from the costs incurred to the difficulty of use (Aubert et al., 2012; Long et al., 2016), which can be fully captured by the concept that Vecchio et al. (2020a) defined as the "complexity" perceived by farmers. Starting from these considerations, the aim of this study is to understand farmers' perspective on the theme. Specifically, "In my opinion, precision farming is…" is the relevant issue from which this research starts. To answer this question, it is necessary to emphasise that the optimisation of production processes involves many dimensions of farms, such as the technological, economic, institutional, and behavioural dimensions (Barnes et al., 2019). These aspects can be interpreted as pieces of a conceptual puzzle, of which some have been widely investigated, while others have not. In the field of research on agricultural innovation, the aspects involved in the sphere of the self of the farmer, that is, “a set of behavioural aspects such as motivation, emotion, relationships, perception and cognition” (Markus and Kitayama, 2010 p. 421), have been less explored. Only a few authors have explored this dimension, mainly addressing the theme of perception (Reimer et al., 2012; Methorst et al., 2017; Knickel et al., 2018; Vecchio et al., 2020a). These studies have described perception as a functional variable in the adoption process, defining the main links with other pieces of the puzzle. In the complex adoption framework, our aim is precisely to colour the picture of farmers' sphere of self and, more specifically, farmers’ perceptions. This study, however, intends to attribute to perception a character of exceptionality due to its subjective nature as an element belonging to the cognitive sphere. For this reason, this work proposes to study the adoption process by proposing a theoretical framework in which perception is isolated and analysed on a different level than that of the other pieces of the puzzle. Such analysis enables us to capture the views of farmers by overcoming the inevitable bias caused by the design of surveys aimed at establishing functional links (Barnes et al., 2019). To that end, our survey focuses exclusively on farmers’ perceived meaning of the term “precision farming”. Furthermore, we accept the relevance of subjectivity in filling the content of the sphere of the self. Going into the cognitive sphere in the context of the self means carrying out an in-depth investigation. As with any survey and methodology chosen, it involves having biases but at the same time being able to collect very detailed information that is difficult to capture with quantitative techniques and tools. Although the results obtained cannot be generalised, they represent important insights and enrich the knowledge of the subject under analysis. Consistent with these aims, we use the Q methodology (QM), theorised by Stephenson in 1935 and defined by Brown (1980) as a "bridge". According to Durning (1999) and Ellis et al. (2007), the QM is useful for analysing the transition between positivism and post-positivism (Durning, 1999; Ellis et al., 2007) aimed at the study of subjectivity. It mixes qualitative approaches, which are necessary to capture the multiple facets of subjectivity that escape numerical reduction, with quantitative techniques that help to measure results. Our work takes into account a purposive sample of 23 farmers, and the application of the QM has allowed us to identify prevailing discourses whose interpretation contributes to enriching the debate on PF, providing a new perspective on the subject to policy makers. Additionally, the QM can be used to rethink policies for the dissemination of innovative tools, and, in this regard, provide a better understanding of the transfer of innovation to the agricultural sector to improve the effectiveness of innovation policy. Finally, the discourses of this study can provide new insights to boost responsible policies, even more so since RRI applications to PF are quite limited.

The article consists of an introduction, followed by the theoretical background in which the transfer of technology for innovation processes is explored. Then, the key dimensions influencing PFT adoption are discussed, including the sphere of the self. In the third section, the methodology is presented, followed by the results. The discussion and conclusions close the work.

2. Theoretical Background: The complexity of technology transfer for innovation processes

In the period of agricultural modernization, innovation has been conceptualised as a linear and unidirectional flow of knowledge of a top-down type from researchers to farmers (Rogers, 1962). During the 1960s, the innovation process shifted from a “science push” model to a “market pull” model, underlining the role of demand (Cook and Morrison, 1961; Hayes and Abernathy, 1980; Rothwell, 1994). These approaches, defined as technology oriented, aim to study the innovation process only through technical and economic factors (Knickel et al., 2009). Over time, these trajectories, strongly disconnected from the needs of farmers and from the context in which innovation operated, led to explorations of more systemic approaches to innovation, such as the agricultural knowledge and information system (AKIS) and, later, the agricultural innovation system (AIS) (Roling and Engel, 1990; World Bank, 2006; Knickel et al., 2009; Schut et al., 2014). In fact, it was only in the 1990s that innovation was conceptualised as a contextualised "networking process", implying a learning process between actors. It is precisely this new conceptualisation that marked a change from "top- down" to "bottom-up" approaches, where science and technology are embedded within a social and institutional context (Klerkx et al., 2012). The contextual inclusion of "innovation processes”, well explained by Elzen et al. (2012) with the term "anchoring of innovation", has been highlighted for adoption in the PF field (Welter, 2011; Tey and Brindal, 2012). The literature has shown how anchoring mechanisms are an optimal strategy fostering an environment that is conducive to scaling innovation in this field (Geels and Shot, 2007; Schut et al., 2020; Seifu et al., 2020; Vecchio et al., 2020b). On the one hand, this evolution reflects the complexity of anchoring innovation processes in agricultural systems; on the other hand, it reflects that farmers’ thinking has played an increasingly active role in innovation processes over time (Klerkx et al., 2012). Hence, there are numerous contributions that researchers have proposed to try to identify the drivers of and barriers to adoption at the farm level.

2.1 The process of adopting PFTs and the role of farmers' perceptions

Even though governments, industry and funding agencies have made efforts to persuade farmers of the benefits of PF, adoption has been low or fragmented. Together with the analysis deepening the complexity of the transfer of innovation, researchers have tried to assess the reasons for this low uptake. First, numerous studies have tried to determine the characteristics of adopters and the contextual factors based on which farmers may more easily accept a new technology in their management (Ghadim et al., 1999; Reichardt and Jürgens, 2009; Barnes et al., 2019). Most studies have pointed out that young farmers appear to be more involved in agricultural innovation (Kutter et al., 2011; Watcharaanantapong, 2012). The reasons for this propensity lie in the fact that new generations report a higher level of education and, at the same time, a growing need for information, which is similarly positively correlated with adoption, in addition to greater exposure to and familiarity with virtual technologies (Tey and Brindal, 2012; Lapple et al., 2015). The need to acquire skills in the use of these tools is also combined with the high investment cost of these tools. In fact, with their ability to absorb costs, large farms have been described as being more willing to adopt innovation. Small enterprises can become PFT adopters through contractors or partnerships (Hategekimana and Trant, 2002). At the same time, the labour intensity indicator gives a clearer idea, in relation to the production activity analysed, of how much agricultural activities are accompanied by new tools or whether manual labour is still present. A relationship emerges between high values and the propensity to adopt PFTs (Vecchio et al., 2020c).

The role of adopters in the context in which innovation operates has been widely investigated in the literature by identifying numerous dimensions concerning not only the structural dimension and farmer perceptions but also the institutional context (Welter, 2011; Barnes et al., 2019; Kebebe, 2019). In particular, the institutional context includes social and cultural dynamics and environmental and policy aspects (Archer et al., 2008; Markus and Kitayama, 2010).

To understand adopters, researchers have explained how the decision to adopt is only partly linked to the structural and institutional dimensions of farms (Barnes et al., 2019). Among the factors already mentioned, some studies (Tey and Brindal, 2012; Methorst et al., 2017) also include the perceptions of farmers.

Perception is the result of a subjective assessment made by the potential user regarding the attributes of innovation (Aubert et al., 2012) and the influences exerted by the structural and institutional dimensions in orienting behaviour in the adoption process (Markus and Kitayama, 2010; Reimer et al., 2012). Among the attributes, many authors have focused on the perceived relative advantage (Rogers et al., 2005; Long et al., 2016) and, in particular, farmers' profitability (Walton et al., 2008). Others have highlighted that the perception of the technological and organisational complexity of innovation can significantly influence adoption (Larson et al., 2008; Robertson et al., 2012; Vecchio et al., 2020c).

Many theories have tried to explain behaviour in the adoption process by emphasising the role of perceptions, the figure of the adopter and background factors (Joffre et al., 2017; Taherdoost, 2018). Since the 1960s, the early theories and models of technology acceptance and adoption have emphasised the role of behaviour and perception as key variables in the adoption process. Fishbein and Ajzen's theory of planned behaviour (TPB) (1975) and later extensions postulated that the individual's behaviour is the result of multiple components, such as attitude, subjective norms, and perceived behavioural control. In social cognitive theory (SCT), Bandura (1986) reports how behaviour, personal factors (personality, cognitive and demographic aspects), and the external environment of the individual are bidirectionally connected in understanding the adoption process.

Davis (1989) theorised differently in his technology acceptance model (TAM) that attitudes are the determinants of behavioural intentions to perform an action or not and are based on perceived ease of use and perceived utility (Davis, 1989; Bishop et al., 2010; Reimer et al., 2012). The TAM itself has been extended by exploring the determinants of perceived utility and perceived ease of use, introducing the relationship between them into the structural dimension (Venkatesh et al., 2008).

These theories are the starting point and lay the groundwork for investigating the links between i) contextual and structural factors, ii) perceptions, and iii) behaviour that could predispose individuals to adopt new technologies. However, in these models, where perceptions or behaviour is taken into consideration, the agent is always considered rational (Knowler and Bradshaw, 2007). This is the vision offered by classical economics, in which the actor manifests autonomous and fiXed preferences disconnected from the context (Kahneman, 2003, 2011; Hoff and Stiglitz, 2016).

In contrast, in behavioural economics or in the field of sociology, researchers have spoken of "quasi-rational actors" and even "enculturated" decision makers, whose perceptions and behaviours are shaped by the context (Fiske et al., 1998; Markus and Kitayama, 2010; Hoff and Stiglitz, 2016). The perception-behaviour link has been widely recognised in the psychological research field, which addresses how "perceptions guide action but so too do actions influence what is perceived" (Vernon et al., 2015 p.1). The role of the self in this linkage has been highlighted by Jaswal (2016, p.1), affirming that "perception-action coupling is not only manifest in the behavioural arena, but also shows up in the internal processes of the agents, particularly those related to the self". This is confirmed by Markus and Kitayama (2010), who discuss a mutual and dynamic constitution of context and the self. For example, regarding the concerns of the self, perceptions are subjected to profound social and non-social influences exerting lasting effects on the behaviour and in the moment of decision making due to the context to which individuals have been exposed until that moment (Di Maggio, 1997; Cialdini et al., 2006). Reimer et al. (2012) is one of the few studies that in the field of adoption that analyses how the characteristics of farmers and farms as well as the and farm context can shape the perception of a new technology and, consequently, the individual's behavioural intentions towards it.

The literature shows the enormous efforts made, especially regarding three aspects: codifying the phases of technology diffusion, theorising adoption models, and identifying the major drivers of and barriers to adoption and all its influencing factors. It is possible to summarise the points previously discussed as follows.

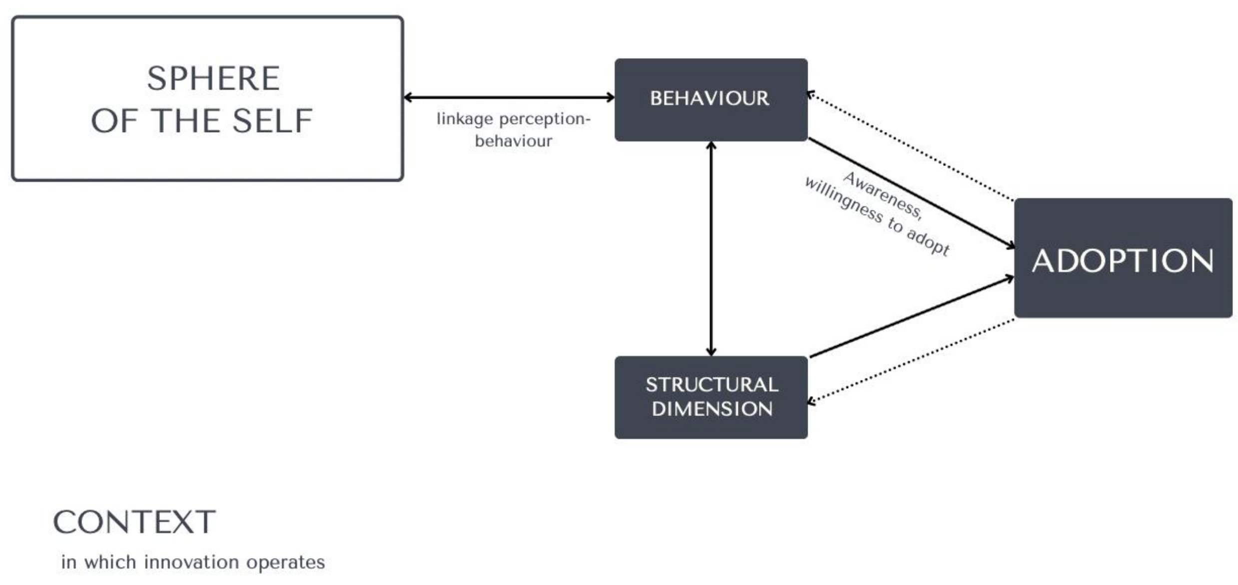
- Adoption is a social process that should be studied with structural factors, the concerns of the self, and institutional factors, which probably cannot be explained by a single theory (e.g., TAM, TPB, theory of diffusion, SCT) but, rather, by a combination of theories (Fishbein and Ajzen, 1975; Bandura, 1986; Davis, 1989; Venkatesh et al., 2008; Straub, 2009; Reimer et al., 2012).

- The role of the self in the adoption process has been highlighted in the sociological field, based on which an "encultured" decision maker is described (Jaswal, 2016; Markus and Kitayama, 2010; Hoff and Stiglitz, 2016)
- In the agricultural field, progress has been made in investigating the role of the self. In particular, a few studies have deepened the understanding of adoption, proposing models by emphasising the perception-behaviour link and their relationships with structural dimensions (Lugandu et al., 2012; Reimer et al., 2012; Schirmer and Bull, 2014; Methorst et al., 2017; Knickel et al., 2018; Ntshangase et al., 2018; Acheampong and Cugurullo, 2019; Vecchio et al., 2020a).

Despite the extensive literature dealing with this subject, there is a lack of research evaluating the direct perspective of farmers based on the sphere of the self. Against this backdrop, it is necessary to find approaches to understand the real perspective of farmers. This paper tries to answer the question "What do farmers really think about PF?" to arrive at a more systemic and holistic understanding of innovation processes in agriculture.

In this framework (Fig. 1), several elements known in the literature about the transfer of innovation are underlined: the process is not linear but holistic (Knickel et al., 2009), with a circularity of influences; and behaviour and structural dimensions play crucial roles in the intention to adopt (Barnes et al., 2019). The most important aspect to emerge is the role played by the self, which represents the "cornerstone" for the whole process, the piece of the puzzle that summarises all the external and internal variables of the individual and that generates and conditions the whole sequence.

Figure 1 – Conceptual Framework



3. How can farmers' real perspective be analysed? An application of the Q methodology

To analyse the sphere of the self, agricultural research has used either quantitative or qualitative methods. According to studies (i.e., Pierpaoli et al., 2013; Ahmed and Haq, 2019), both methods present limitations: quantitative methods are not suitable for modelling that which falls within the sphere of subjectivity (Durning, 1999), while qualitative methods, despite being able to better capture the cognitive sphere, translate the results with ambiguity and pose the problem of generalising the results (Lawlor, 1996).

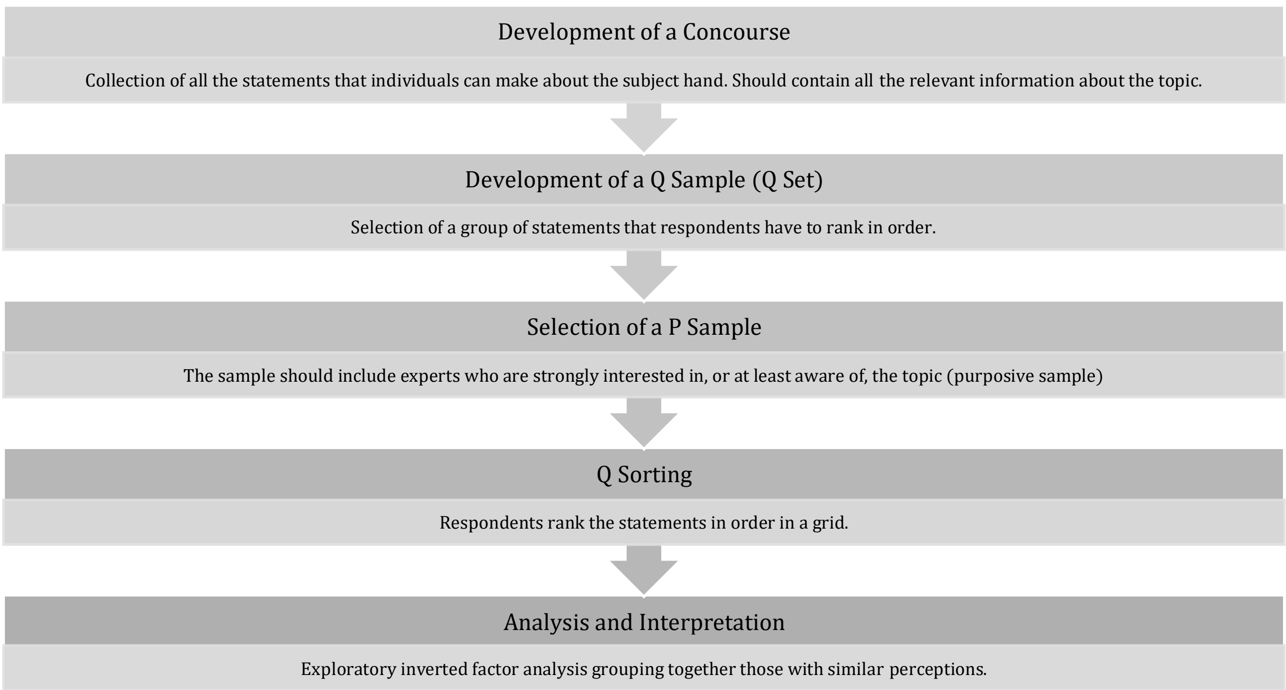
To overcome this limitation, the literature has suggested the use of hybrid methodologies (Guerin et al., 2018), and among them, the QM is increasingly appreciated by researchers and analysts (Cools et al., 2009; Yarar and Orth, 2018). The QM starts from the theory of limited independent variety (Keynes, 1921) or from what Stainton Rogers (1995) calls "finite diversity", with the aim of collecting and exploring the variety of relationships that individuals construct (Kitzinger, 1987). This is possible when, in QM-based studies, participants are presented with a heterogeneous set of stimulus items, i.e., the “Q set”, which they must actively rank in order (Watts and Stenner, 2012). This task allows them to focus on their subjective experience. Thus, it is not only the "builders" ((the participants) who are at the centre of the method but also the "constructions" themselves (Stainton Rogers, 1995). The main purpose of the methodology is to discern the perceptions of people about their world from the self-referential perspective, making it possible to comprehend subjectivity (McKeown and Thomas, 2013). This approach permits us to obtain "socially less desirable" responses than Likert measures (Fluckinger, 2014). Socially desirable responses influence psychometric tests, especially if obtained with a Likert scale (Hough and Oswald, 2008), and can hardly be regulated with an artifice or a measure after detection, which generally occurs with a scale involving social desirability (Podsakoff and Organ, 1986; Spector, 2006). Thus, the QM represents a strategy for analysing socially desirable responses, distinct from the social desirability trait as commonly measured (Zerbe and Paulhus, 1987), trying to limit the individual's behaviour and allowing a significant non-cognitive construct. As defined by Brown (1997), the QM is a quali-quantological approach that allows the study of complex phenomena on which various different perspectives can exist, thus representing a bridge between quantitative and qualitative approaches (Sell and Brown Steven, 1984; Dennis and Goldberg, 1996; McKeown and Thomas, 2013). For these reasons, the methodology is often used to observe attitudes (Cross, 2005), allowing a reactive but statistically rigorous approach to subjective perceptions (Barry and Proops, 1999).

In fact, while a typical quantitative analysis (for example, factor analysis) focuses on the discovery of correlations and models through variables, the QM aims to reveal correlations with a measure of the nature and extent of the relationship between people (Watts and Stenner, 2012). The "quantitative" analysis step is then used to identify correlations within individual responses, followed by a qualitative interpretation to investigate personal beliefs, perspectives and meanings regarding a given topic (Previte et al., 2007; Vecchio et al., 2020d). Therefore, the QM allows researchers to compare the similarities and differences between subjective viewpoints and, ultimately, to construct consumption segments that share an "underlying secular theory" (Brown, 1993), with the aim of assigning an a posteriori significance through the researcher's interpretation of the selection distribution (Brown, 1980).

4. Method

The QM that we employed in this work is based on the five-step procedure shown by McKeown and Thomas (2013). The five steps are outlined in Figure 2.

Figure 2 – Steps in the Q Methodology



Source: our elaboration based on the five-step procedure of McKeown & Thomas (2013)

To carry out this analysis, the first two steps are the most important; defining the "concourse" and creating the Q set can affect the whole analysis. The former is the raw material of the Q study that provides the “self-referent notions” (Stephenson, 1953) arising from shared understanding, whose specific meaning may differ depending on the context (McKeown and Thomas, 2013). Since the volume of the concourse can be infinite, it has to be dimensionally reduced to obtain the Q set, which is the collection of statements related to the most important aspects of the study theme (Brown, 1980). The sentences included here should represent a variety of different opinions and feelings rather than being limited to concrete facts (Brown, 1993). Following the procedure shown by McKeown and Thomas (2013), the concourse was built using scientific publications, newspapers, farmer blogs or interviews, conversations, commentaries, and texts related to the subject. From this review, we defined a final concourse composed of 80 statements (annex 1 - Concourse). Using an inductive approach (Glaser and Strauss, 1967), the analysis shows that several dimensions influence farmers’ perceptions of PF and its adoption. These dimensions are not a strict categorisation; rather, they represent a guide to ensure coverage of the most relevant aspects related to farmers’ opinions on PF. Several rounds of discussion were implemented among researchers to delete and rephrase redundant and unclear statements. At the end of the described procedure, the initial list was refined into a more comprehensive Q sample composed of 33 statements. Q samples must be composed of statements that are “natural” in the language of the participants and “comprehensive” in their representation of the subject (McKeown and Thomas, 2013) to provide individuals with the opportunity to best express their personal opinions (Watts and Stenner, 2012). Consequently, the use of academic language should be avoided to facilitate understanding, and a balanced number of positive and negative statements should be included to avoid opposites or similar statements (Stephenson, 1953). Small sheets of paper are used to print the declarations, which are also identified with a code (Brown, 1993) that cannot influence the participant during the process. Before being administered to the sample, the test was tested by a collaborator. In our case, the list of declarations was chosen based on the literature on precision agricultural tool adoption, focusing on drivers and barriers. In the third phase, it is necessary to select participants (the so-called P set) who are theoretically relevant to the research question (Van Exel and De Graaf, 2005) and who have a defined perspective to express what matters in relation to the topic (Watts and Stenner, 2012).

This interview method was first tested among the members of the research group to determine the best way to submit the questionnaire. After a test, it was decided to proceed from the sociodemographic questions and then proceed to the Q sorting phase. The P set is usually smaller than the Q sample, typically from 10 to 40 people (Brouwer, 1999). The reason for this can be found in an ancient maxim attributed to Roman Emperor Marcus Aurelius, who stated that "*the opinion of 10,000 men has no value if none of them knows anything about the topic*", leading us to the choice of a purposive sample of farmers who have at least "heard of" PF (Coleman et al., 1955). Therefore, an intentional sample of 23 farmers was selected. The interviews were conducted by two researchers who selected the respondents based on the question "*Have you ever heard of innovation, technological innovation, or precision farming in agriculture?*" This allowed us to select only those agricultural entrepreneurs who had the necessary conditions to carry out our questionnaire.

The interviewees were asked to voluntarily participate in the study.

No financial compensation was promised or subsequently awarded. They were informed of the objectives of the investigation, the duration of the interview, and the possibility of abandoning the investigation at any time, and they were given the contact details of the principal investigator for any clarifications or indications on the matter. The interview was conducted by starting with a conversation to retrieve some basic information, such as the socio-structural characteristics of the farm, and it then proceeded to the Q sorting phase. This was carried out by making a sign with the grid, which was completely white so as not to influence the respondents, and providing them cards with statements. The researchers actively supported the respondents in case they had questions. Each interview lasted between 45 minutes and 90 minutes. The interviews were carried out based on the respondents’ knowledge ("heard of “) of PFTs, and they were conducted during three agricultural fairs, one in Bologna (representative of northern Italy), one in Rome (representative of central Italy) and one in Matera (representative of southern Italy). The interviews were conducted in a face-to-face manner through the use of a poster. Based on the traditional scheme, this format has favoured the Q sorting phase. The composition of the sample defined itself through the filter question "In my opinion, precision farming is…", and the number of interviewees was defined a priori by the authors in a manner consistent with Watts and Stenner (2012), who reported that the number of respondents should be less than 70, representing nearly half of the selected items. Phase 4, Q sorting, is the moment when the interview takes place. All participants received detailed instructions (in writing) to complete the questionnaire together with the statements and a card for the socio-demographic data. Initially, the participants classified the declarations (reported in Table 3) about “*In my opinion, precision farming is*…” into three groups (agreement, disagreement or neutrality) and subsequently ordered these in slots of an almost normal forced choice distribution of 9 total points on paper (Fig. 3), ranging from “completely disagree” (—4) to “neutral” (0) to “completely agree” (4) (Brown, 1980; Davies and Hodge, 2007). In this way, the numbers of the Q sample items are recorded in the slots that replicate the distribution of the items for each of the Q sorts (McKeown and Thomas, 2013).

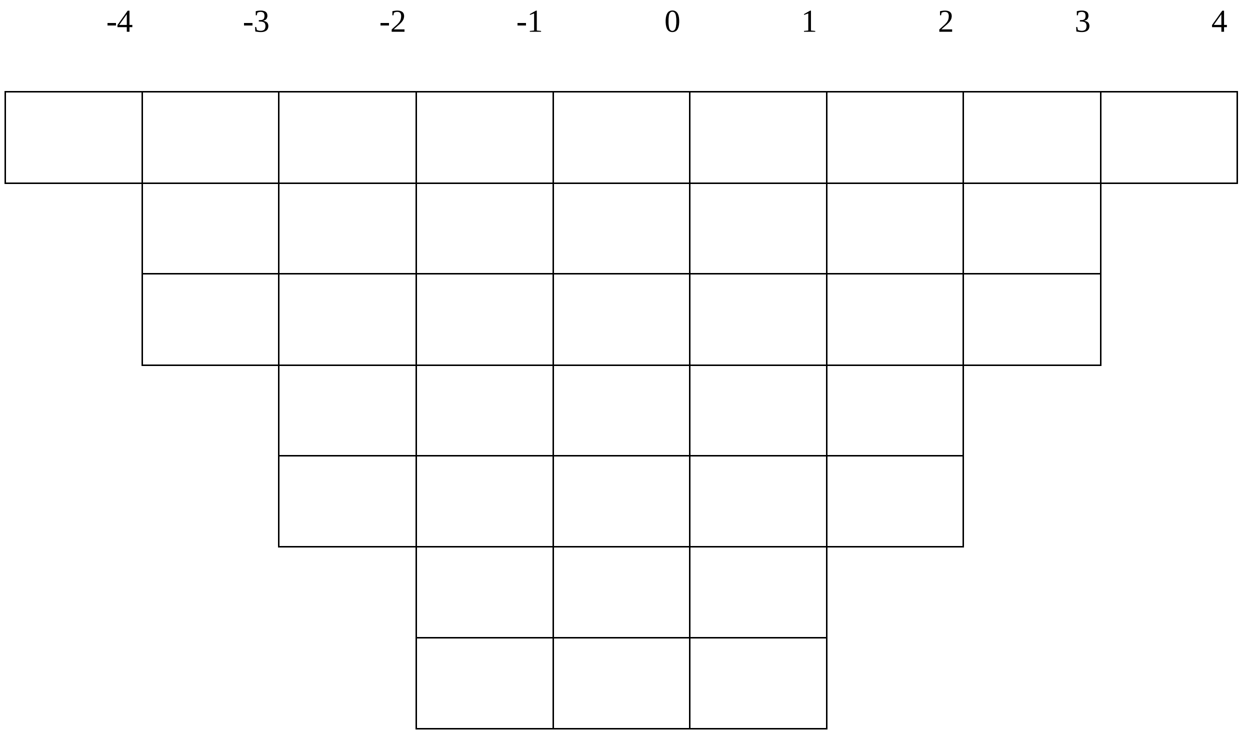


Figure 1 – Example of the Fixed Quasi-Normal Distribution. Values are ranked in a range from -4 to 0 to +4. A total of 33 items could be accommodated in the distribution illustrated.

This type of distribution, which follows a normal distribution and thus forces a number of items towards the midpoint, should facilitate the process of standardisation of the sorting procedure and was considered by Stephenson to be the prearrangement of choice for gathering QM data. This process has become the standard approach of the methodology (Watts and Stenner, 2012). Watts and Stenner (2012) suggest collecting more information after the Q sort to better interpret the answers. For this reason, after sorting, additional data were collected, particularly regarding the respondents' personal data (age, gender, education, in- come, position, etc.). Finally, an inverted factor analysis is carried out (Stephenson, 1935; Fleiss, 1971) since a typical factor analysis directs its focus on the discovery of correlations between variables, while the QM correlates and factorises people (Watts and Stenner, 2012; McKeown and Thomas, 2013). Factor analysis is then used to identify correlations within individual answers, and it is followed by a qualitative interpretation to show personal beliefs, perspectives and meanings regarding a given topic (Previte et al., 2007). The analysis was run with KADE v1.2.0 software.

5. Results

5.1 Sample characteristics

The analysed sample (Table 1) has a slight prevalence of men (53%). The age of the interviewed farmers is wide, varying from 25 to 55 years. The farm size is also quite varied, although the average farm size is higher than the national farm size of 8.4 ha (CREA, 2020) and amounts to more than 43 hectares. All companies employ family manpower with a minimum of 1, i.e., only the spouse, and up to 5 members. Approximately 60% of the sample claims to have organic production. The degree of PFT adoption is quite high (1 out of 3 respondents says that he/she is already adopting), while 50% say they will adopt in the near future. As shown in the table, the companies interviewed have an equal distribution between northern, central, and southern Italy.

Table 1: Sample

Variable	Minimum	Maximum	Average
Age	25	55	38
Utilised Agricultural Area (UAA)	1	130	42.09
Family component involved in the farm	1	5	2.5
		Frequency	Percentage
Education	*Primary*	0	0
	Secondary	7	30.43%

	Bachelor's degree	10	43.48%
	Master's degree	6	26.09%
Organic production	*Yes*	13	56.52%
	No	10	43.48%
Innovation adoption	*Adopter*	6	26.09%
	Non-adopter	7	30.43%
	Planner	10	43.48%
Location	*North*	9	39.13%
	Central-South	14	60.87%

5.2 The analysis

The QM allows us to identify some common factors in individuals' perceptions of the PF theme. The intercorrelation matrix was realised through the centroid procedure, translating the solution through the use of varimax rotation, which is considered the best solution for the QM (Watts and Stenner, 2005). Subsequently, through the criterion of eigenvalues greater than one (Rajé, 2007), 5 factors were selected, and the characteristics of the factors are presented in Table 2.

Table 2: Factor characteristics

	factor 1	factor 2	factor 3	factor 4	factor 5

No. of Defining Variables	7	4	3	4	5
Avg. Rel. Coef.	0.8	0.8	0.8	0.8	0.8
Composite Reliability	0.966	0.941	0.923	0.941	0.952
S.E. of Factor Z scores	0.184	0.243	0.277	0.243	0.219

The five groups of discourses we discovered are shown in Table 3. The factor scores are the result of weighted averages (Z scores) of the values given to each statement during the Q sorting phase. In Table 2, the Z scores are converted into the original scale values (-4 to +4) to provide a clearer representation (Ellingsen et al., 2010).

Table 3: Statements

N.	Statement	Group 1	Group 2	Group 3	Group 4	Group 5	Z Score variance
1	the use of new technological tools in agriculture to reduce production costs	0	2	-2	3	2	0.698
2	the use of new technological tools in agriculture to increase my yields	3	-1	3	-1	3	0.483

3	the use of new technological tools in agriculture to increase product quality	4	1	3	1	-1	0.518
4	the use of new technological tools in agriculture to be more environmentally sustainable	1	3	-1	-4	-4	1.686
5	relevant to my current practices (not optional)	0	0	-3	1	-3	0.703
6	the use of new technological tools in agriculture to be more efficient (maximise the ratio between input and output)	2	1	2	2	1	0.041
7	difficult without financial support (e.g., bank loans, etc.).	0	-3	-2	-1	3	0.85
8	too complex for my knowledge/experience	-3	-1	4	1	0	1.07
9	an easy-to-understand technology	-2	-2	-2	-4	4	1.342
10	an easy-to-use technology	-2	3	1	-2	-1	1.161
11	a very expensive investment	-1	-1	0	0	2	0.265
12	a technology that develops with the presence of innovation services	3	0	2	-3	0	0.754
13	a very widespread technology in my territory	-4	1	-3	1	-4	0.853
14	a practice that fits my business model	-1	-1	1	4	-2	0.937

15	the use of new technological tools in agriculture to make the management of my farm easier	1	2	2	-1	1	0.138
16	the use of new technological tools in agriculture requiring organisational and structural adaptations that are difficult to implement	-1	0	4	-2	-3	1.239
17	the use of new technological tools in agriculture requiring radical changes in current agricultural practices	-1	-1	0	2	-2	0.273
18	the use of new technological tools in agriculture requiring training/information costs	2	1	1	-3	3	1.021
19	the technology that supports my decisions by monitoring my activity	3	3	0	2	0	0.266
20	the use of new technological tools in agriculture that is associated with economic risk that is too high for my company	-3	0	-1	3	-1	0.878
21	the use of new technological tools in agriculture that partly replaces the labour force	1	-2	-1	-1	1	0.351

22	necessarily supported by economic or training support measures	1	0	1	-3	-1	0.345
23	a practice that makes my job easier to do	2	-2	2	3	0	0.503
24	a practice that gives me confidence and that I would recommend to others.	0	2	1	2	-2	0.505
25	a technology to improve the working conditions of the employees in the company	0	-2	-3	-1	0	0.343
26	a widespread reality in the Italian agricultural sector	-3	2	-4	4	1	1.524
27	a technology suitable for large companies	-2	-4	-1	0	4	1.709
28	a technology that involves only young farmers	-4	-3	0	0	2	0.814
29	impossible without a computer or an internet connection	-2	4	3	0	1	1.321
30	difficult in the agroecological context in which I live	-1	-4	0	0	-1	0.59
31	a strategy that can be pursued only through the development of an environment that sees the collaboration of research institutions, the territory and the agricultural world	1	4	-2	1	-3	1.266

32	a technology that gives me a competitive advantage	4	1	-1	-2	2	0.642
33	practicable if supported by a producer organisation	2	-3	-4	-2	-2	0.813

The five discourses were analysed by examining the statements that most represented the discriminating points or the points of contact between the different perspectives. Once this had been done, it was possible to define the discourses as follows:

Discourse 1: "The key to success"

Members of this group strongly agree that PF is the use of new technological tools in agriculture to increase product quality and yields and that it gives the adopter a competitive advantage. These respondents do not think that PF is too complex for their knowledge or experience, and they do not associate the use of new technological tools with economic risk that is too high for their business. The entrepreneurs in this group do not think that PFTs are technologies that involve only young farmers or that they are a very widespread technology in their territory and in the Italian sector. They agree on the fact that PFT are a technology that supports decisions by monitoring their activity, and they think that PFTs develop in the presence of innovation services.

Discourse 2: "A way for sustainability"

The members of this group agree on thinking that PFTs are a technology that supports their decisions by monitoring their activity and strongly believe that they would be impossible to use without a computer or an internet connection. They strongly agree with the fact that PF is a strategy that can be pursued only through the development of an environment that sees the collaboration of research institutions, the territory and the agricultural world, and in contrast, they do not consider producer organisations to be a necessary element to achieve it. PFTs are considered an easy-to-use technology that does not involve only young farmers. The farmers in this group do not see PFTs as a suitable technology for large companies, and they do not think that they are difficult to implement without financial support such as bank loans. They strongly disagree with the fact that PF is difficult to enforce in the agroecological context in which they live, and they connect the use of PFTs with major environmental sustainability.

Discourse 3: “Something far from me”

The entrepreneurs in this group agree that the use of new technological tools in agriculture can increase their yields and the quality of their products. As PF is considered too complex for their knowledge and experience and impossible without a computer or an internet connection, they think that PF requires organisational and structural adaptations that are difficult to implement and that a producer organisation is not enough to practice it. The members of this group do not consider PFTs to be a widespread technology in their territory or in the Italian agricultural sector. PF is not considered relevant to their current practices, and they do not feel that PF could improve the working conditions of the employees in the company.

Discourse 4: "I don't really realise the usefulness"

The farmers in this group strongly consider PF to be a practice that fits their business model and that can make their job easier to carry out, even if it is not easy to understand how it works. They are the only respondents to strongly think that PF is a widespread reality in the Italian agricultural sector and that it can develop without the presence of innovation services. The entrepreneurs in this group consider it the use of new technological tools in agriculture to reduce production costs but not to be more environmentally sustainable, and for them, PF is associated with an excessive economic risk for the company. PF is not considered the use of new technological tools requiring training and information costs or support by economic and training measures.

Discourse 5: “Yes, but no thanks”

The members of this group consider PFTs to be an easy-to-understand technology that is suitable for large companies, but they do not think they are relevant for their current practices or that they are widespread in their territory. They think that PFTs are difficult to implement without financial support and that they requires training and information costs. The necessary structural and organisational adaptations for this kind of activity are considered to be difficult to implement, but the farmers in this group do not consider external collaboration the only way that can be pursued. They strongly disagree with the fact that PF corresponds with the use of new technological tools to be more environmentally sustainable, but they agree with the use of these tools to increase yields.

The analysis of the discourses shows us five different thoughts on PF. The five thoughts have in common two key dimensions that are interrelated to each other, which are the propensity to innovate and the perceived complexity of using tools, which can be represented in a graph by classifying the two dimensions (figure 2)

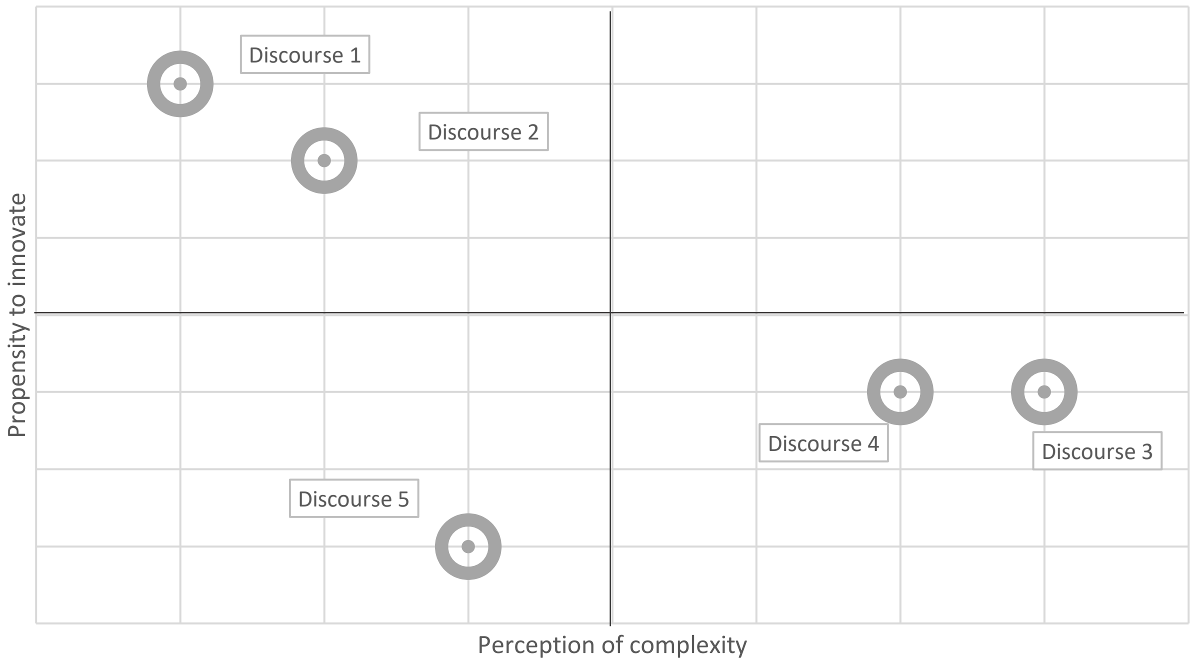


Figure 2 – Discourse Positioning Diagram based on the Propensity to Innovate and Perceived Complexity

5. Discussion and Conclusion

The aim of the work was to understand Italian agricultural entrepreneurs' perspectives on PF to determine the role and strategic importance that PF tools could have for the sector. To achieve this aim, it was necessary to explore the sphere of the self. To measure the role of farmers' sphere of the self in the adoption process, this paper proposes the use of the QM to identify discourses that could play a predominant role in the formalisation of the adoption process. From the analysis conducted through a quali-quantitative approach, 5 predominant perspectives that contain and summarise many of the barriers and drivers found in the literature (Long et al., 2016) emerged, highlighting how the complexity of use and the understanding of these innovative tools are the most important components from the entrepreneur's perspective (Aubert et al., 2012; Vecchio et al., 2020a). The perspectives have elements of contact and strong differences. Discourse 1 is the only discourse that sees PFT as something that could give farmers a competitive advantage and the only discourse that sees it feasible when supported by a producer organisation. Discourse 2 is the only discourse to strongly think that PFTs are a set of technologies that can increase the environmental sustainability of the company, while the others, especially Discourses 4 and 5, strongly disagree with this statement. Discourse 2 is also the only discourse that relies more on collaboration with others, especially compared to Discourse 5. Discourse 3 includes those who consider PF too complex for their knowledge and experience and those who see it as the use of new technological tools in agriculture requiring organisational and structural adaptations that are difficult to implement. Their idea that PF is something difficult to achieve without equipment such as computers and the internet is shared with Discourse 2. Discourse 4 includes those who have the highest consideration of PF as a practice that fits their business model even if they have the strongest idea of it as a technology that is not easy to understand, and they are the only farmers to see it as a widespread reality in the Italian agricultural sector. He members of this discourse are the only ones who do not see it as the use of new technological tools in agriculture requiring training and information costs; furthermore, they have the lowest agreement on the fact that PF has to be supported by economic or training support measures. Discourse 5 is the only discourse that considers PFTs to be an easy-to-understand technology that is suitable for large farms. They think that PF requires training and information costs and that it is a difficult activity to be carried out without financial support. Nevertheless, they have the strongest consideration of PF as a strategy that can be pursued even without the collaboration of institutions or other farms. The members of all groups consider PF to be the use of new technology to be more efficient by maximising the ratio between input and output to a slight extent.

The extracted perspectives answer the research question we asked ourselves at the beginning of the work, that is, "*precision farming for me is…*", delving into the cognitive sphere of entrepreneurs. Unlike other works in the literature, this study extends beyond the perception-adoption link (Reimer et al., 2021), but we try to outline those thoughts that can be useful to stakeholders and policy makers to better understand the PF phenomenon. The aim of this paper was "*to colour the picture of farmers' perception*", and the analysis provided five different "*colours*" to better outline the picture of the puzzle pieces. In fact, using the QM, we were able to outline 3 macro approaches:

- The "proactive approach" shared by Discourses 1 and 2. The first two discourses share a proactive attitude towards PF. The first perspective summarises the PF concept as the only possibility to face the challenges of the future and as the only way to adapt to a changing scenario. The second summarises the utilitarian vision of these instruments as the optimal solution to improve the environmental and economic sustainability of businesses. In both visions, it is perceived that PF now plays a key role in agricultural enterprises.
- The "*conservative approach*" shared by Discourses 3 and 4. The two discourses are connected by the perception of complexity that individuals have with regard to PF. The third discourse is characterised by distrust of innovations, while the fourth is characterised by a conservative vision.
- The "*doubtful approach*", introduced by Discourse 5. This approach summarises the more sceptical visions.

Furthermore, it could be important to emphasise that the self-selected sample of respondents belonging to these 3 approaches is, on average, composed of young people (under 40 years of age), confirming studies reporting that the propensity for knowledge and adoption of new technologies in agriculture is a prerogative of young actors (Larson et al. 2008; Kassie et al., 2013). This study highlights a possible lack of knowledge and information in the advanced age groups, who decided not to respond to our investigation and who, according to the literature, rely mainly on their experience rather than digital support in their farm management (Khanna, 2001) and rarely appear as experts in this kind of study. The QM could be a useful method for answering the question "*What do* *farmers really think about PF?",* revealing in our results some relevant perspectives of Italian farmers and overcoming the limitations of qualitative and quantitative methodologies in studying the self.

Given our results and in the context of innovation processes in agriculture, we believe that a mixed method, such as the QM, allows us to colour the piece of the cognitive sphere, which we have set ourselves to investigate. This opens the door for future developments to research to understand the interactions between the cognitive sphere and the other pieces of the puzzle to arrive at a more systemic and holistic understanding of innovation processes in agriculture.

This analysis provides new contributions to the study of PF adoption, focusing all the attention on the perspectives of entrepreneurs rather than making another classification of the business types more or less inclined to adopt PFTs.

The results contribute new evidence for the debate on PF, providing policy makers with a new perspective on the subject, giving them new insights to rethink policies for the diffusion of innovation technologies and, likewise, to encourage actions to prevent the eventual negative impacts of PF. This work provides insights to overcome the constraints highlighted by the doubtful and conservative approaches and to improve PFT knowledge by going beyond socio-demographic barriers.

These considerations are truly topical, in light of what has been discussed at the European level in recent documents on the new programming period (2021-2027). Among the key factors in the development of the European Union, these documents include two themes concerning precisely the cognitive sphere: information and knowledge (EC, 2019). These aspects, if valorised, could represent a turning point to remove doubts and transform negative perspectives into approaches that see PF as a successful way and a useful tool to improve not only agriculture but also the environment.

Analysing the desirability of PF through the RRI lens can give us a further key to interpreting the 3 approaches, as they could have a role in informing *responsible* policies. Indeed, if we were to ask whether PF is capable of changing agriculture in a positive way, it might be likely that the 3 approaches would produce different answers. The "*conservative approach*" is represented by those who could answer this question with a vision of PF that is sceptical of producing positive impacts on the agriculture of the future. Similarly, the "*Doubtful approach*" presents uncertainties related to the perceived effectiveness of innovation. In contrast, the "*proactive approach*" is represented by those who support the potential of TI more, with even different opinions on the type of benefit generated on the basis of the discourses involved (Discourse 1, Discourse 2).

Studies that have proposed the application of RRI dimensions to PF are still limited. Most of those that have done so have concluded that efforts to develop RRI in this field are needed (Eastwood et a, 2019). Additionally, from the present study, it emerges, for example, that the "*conservative approach*" reveals gaps in the inclusiveness of stakeholders, which are linked to the uncertainty regarding how TI can produce benefits for the agriculture of the future. In this regard, the literature has extensively examined the uncertainty surrounding the adoption of technological tools and their consequences from multiple perspectives. First and foremost, uncertainty has been linked to difficulty in recognising the beneficial and negative effects of technology. In this way, exploring farmers' perceptions of expected benefits offers us some insights. Second, the difficulty of communication between PFT providers and users, which is linked to the challenging adaptation and implementation of these tools, adds to the uncertain situation. Finally, market conditions and policy uncertainty play a role in this framework (Long et al., 2016; Eastwood et al., 2017; Eastwood and Renwick, 2020).

Finally, we have the "proactive approach", which supports the efficacy of the technology but which advocates two different discourses: Discourse 1 is supported by those who conceive of PF as a viable way to give the adopter a competitive advantage, offering benefits mainly related to increasing product quality and yields; Discourse 2 is supported by those who likewise have a vision of the future strongly mediated by technology, the use of which allows farm management to be easier with the possibility of increasing environmental sustainability. Both see the use of technology as being strongly linked to the prospect of achieving business improvements. In fact, it seems that the vision of the "*proactive approach*" is that which conceptualises innovation as "*business innovation, strongly market-oriented*", with the aim to "*increase the wealth of the actor(s) who initiate or adopt it*" (Charatsari et al., 2022, p. 4).

The strongly utilitarian view that especially belongs to Discourse 2 emphasises that, with regard to PF, these people probably have developed a "*knowledge of how*" rather than a "*knowledge of principles*", justified by the fact that they claim that TI is easy to use. Most likely, then, as Sahin (2006) reports, this kind of knowledge leads individuals to understand how PFT technically works, but they still need to investigate the broader reasons why it should be applied. The risk in this situation is to act in everyday decision-making processes with a distorted view of the future.

The results of this research suggest that the analysis of bottlenecks to PFT adoption is only the starting point of the potential aspects that contribute to supporting an effective path of responsible innovation, from the company perspective to actions implemented at the policy level. Future RRI efforts require additional efforts from all stakeholders to fully incorporate the dimensions of RRI into PF to create more *responsible* policies.

As the limitations of this study, it addressed only the perspective of farmers. Much more needs to be done in future research to consider the views of all engaged stakeholders (i.e., policy network) as well as normative directions to fully assess the application of the RI framework to PF.

These findings underline the importance of promoting *responsible* policies; at the European level, the Green Deal intends to invest in more environmentally friendly technologies and support both the innovation industry and the effectiveness of innovation policy. This initiative emphasises that the development of TI is critical to facilitating the agri-food sector and, more broadly, the European economy's (De Castro et al. 2020) sustainable transition, which is under pressure to be competitive and resource efficient in the face of massive environmental challenges. In this sense, PF has the potential to facilitate this sustainable transition, although further study is still needed to understand the reasons associated with the low uptake of PFTs, including the sphere of the self. The results of our work, identifying clusters of discourses present in the agricultural sector, could also be useful to inspire non-European researchers to carry out an in-depth research in their own contexts to verify the effectiveness of the measures put in place by local initiatives. In fact, as is well known, the issue of TI in agriculture is not exclusive to Europe and has now become the theme of sector policies at the global level, as shown by the experiences of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia and the Ministry of Agriculture and Rural Affairs (MARA) in China, for example. In this way, the experience of some studies conducted in non-European countries (e.g., Zhu et al., 2019; Tian and Tian, 2021) underlines the mediating role of RI between stakeholder pressure and final company sustainability performance. The application of RRI principles to PF can broaden the debate on the role of *responsibility* associated with promoting an effectiveness innovation pathway, regarding which efforts are still needed in both European and non-European countries.

Thus, promoting the spread of innovation in agriculture, such as TI and smart solutions for organising the production and sale of food products, has become a fundamental objective not only for the development of a country's primary sector but also for the entire global economic system, which today, more than ever, needs security of supply to meet the challenge of "*zero hunger*", which is one of the sustainable development goals proposed by the United Nations.

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Annex 1 – Concourse.

N°	Statements
1	the use of new technological tools in agriculture to reduce production costs
2	the use of new technological tools in agriculture that increase production costs
3	the use of new technological tools in agriculture to increase my yields
4	the use of new technological tools in agriculture to be more sustainable
5	the use of new technological tools in agriculture to change the agricultural practice
6	the use of new technological tools in agriculture to increase product quality
7	the use of new technological tools in agriculture to standardise all productions
8	the use of new technological tools in agriculture to be more environmentally sustainable

9	a technology to improve quantity production
10	relevant to my current practices (not optional)
11	a practice not relevant to my current practice
12	the use of new technological tools in agriculture to be more efficient (maximise the ratio between input and output)
13	difficult without financial support (e.g. bank loan).
14	easy also without financial support (e.g. bank loan).
15	only a digital solution
16	too complex for my knowledge/experiences
17	a technology that involved only super specialized farmer
18	a technology that can create a big added value
19	a technology suitable only for multifunctional farms
20	a technology useful only for commercial activity
21	a technology useful only for industrial activity
22	an easy-to-understand technology
23	a technology that could be useful to improve my personal life
24	an easy-to-use technical technology
25	a difficult-to-use technical technology
26	a very expensive investment
27	a cheap investment for my farm
28	a technology that develops with the presence of innovation services
29	a technology that can be introduced without public support
30	a very widespread technology in my territory

31	a tool uncommon for my territory
32	a tool uncommon for Italy
33	a practice that fits my business model
34	a practice that could change my business model
35	the use of new technological tools in agriculture to make the management of my farm easier
36	an instrument that changes the management of my farm
37	the use of new technological tools in agriculture that could be run only if you are a digital expert
38	the use of new technological tools in agriculture requiring organisational and structural adaptations that are difficult to implement
39	a revolution for the organization of my farm
40	the use of new technological tools in agriculture requiring radical changes in current agricultural practices
41	the use of new tools in field not adapt for my business
42	the use of new technological tools in agriculture requiring training/information costs
43	the technology that supports my decisions by monitoring my activity
44	the use of new technological tools in agriculture that is associated with economic risk that is too high for my company
45	the use of new technological tools in agriculture that partly replaces the labour force
46	necessarily supported by economic or training support measures
47	an individual choice of the entrepreneur
48	the introduction of technological tools in farms to create new type of jobs in agriculture
49	the introduction of technological tools that should be support from the state

50	a way to improve financial conditions of my employee
51	a practice that makes my job easier to do
52	a practice that could be too complex for my employee
53	a practice that gives me confidence and I would recommend it to others.
54	a practice that does not make me feel comfortable
55	a technology to improve the working conditions of the employees in the company
56	a non-ethical choice for my business
57	a danger to human health
58	a practice that worsens the quality of products
59	a practice to replace human activity in my business
60	the use of new technological tools in agriculture that join human capital
61	the possibility to improve knowledge in the farm's activities
62	a widespread reality in the Italian agricultural sector
63	a technology suitable for large companies
64	a technology suitable for every type of farm
65	a technology that involves only young farmers
66	a technology that involves old farmers
67	a technology that involves all type of farmer
68	impossible without a computer or an internet connection
69	impossible without a computer
70	useful only for animal husbandry
71	difficult in the agroecological context in which I live
72	not depending on agroecological context

73	a strategy that can be pursued only through the development of an environment that sees the collaboration of research institutions, the territory, and the agricultural world
74	a strategy that can be perform alone
75	a technology that gives me a competitive advantage
76	only a modernization of my farms
77	only an instrument to run my activity
78	practicable if supported by a producer organisation
79	practicable if supported by university
80	a practice to favour consortium with other farms

Second Chapter

Title page

Technological innovation in Fisheries and Aquaculture: what are the “discourses” of the policy network?

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Abstract

This paper aims to explore the point of view of experts of the Italian policy network of the fisheries and aquaculture sectors on technological innovation. This type of research is still very recent and unexplored, and it is relevant to stress that most studies have been conducted to primarily analyse the point of view of producers. Over the past decades, there is a growing recognition that the adoption of new technological innovation in the fisheries and aquaculture sectors should consider the perspective of all the stakeholders acting on the captured or farmed resource. The perspective of the experts involved in the political processes for the fisheries and aquaculture sectors, or in other word the view of the entire "policy network" remains a little explored field of analysis deserving much more attention. With this purpose, the Q methodology is highlighted as an effective strategy for examining experts' perception toward innovation. The findings indicated four macro discourses summarised in 2 main approaches to innovation: conservative, for which innovation is merely seen as a tool, the potential of which can be found in the perspective of improving company's management; and progressive, which recognises a wider effectiveness of innovation, even outside the functional unit of the company. The results address new perspectives to European policy makers to rethink current policies and in pursuing the goal of the Fisheries and Aquaculture Fund of stimulating the diffusion of innovative technologies.

KEYWORDS: aquaculture, fisheries, perceived complexity, q methodology, policy network, technology adoption

1. Introduction

The blue economy is gaining consensus among European policy makers on the assumption that to be truly green, we should think blue. Effectiveness of the "blue policies" rely on a diversified set of dimensions and actors including policy makers, potential beneficiaries and other stakeholders. This articulated set of actors represents the architecture of what we identify as the policy network, which is the object of this paper. The aim is to investigate the perspectives of the fisheries and aquaculture policy network (FAPN) on the uptake of innovations. We point out that the "policy network" indicates the relationships between the public and private sectors (Vaa Waarden, 1992) and, more specifically, is a policy puzzle to be pieced together. Three layers makes up the puzzle:

- the first, represented by components that actively influence policy formation, such as policy makers or directors of agency/authorities in agrifood systems;
- the second, made up of what are commonly called the intermediate bodies, such as trade associations;
- the third, which includes all those actors of civil society, who for various reasons participate directly or indirectly in the process of policy creation itself, such as academics or citizens, whose relevance has gained ground in recent years: Eurobarometer surveys are taken into great account in the setting up of the policy.

Like the pieces of a puzzle, they all become integral parts for the clear formation of the overall image, thus rebalancing the importance of the layers, placing them on the same level and not hierarchically. A balanced policy network may fill the strategic task of stimulating knowledge transfer and innovation adoption (Vasudeva et al. 2013). Therefore, in order to facilitate effectiveness of the policy action, understanding the point of view of the policy network will be increasingly relevant, as it will be at the forefront in encouraging the primary sector to achieve, supported by innovation, the global ambitious sustainable development goals. This aspect deserves more attention and our paper tries to fill a gap in literature.

Among the sectors in the front line, the primary sector is undoubtedly the flagship, but the fishing and aquaculture sectors are also becoming key players. The "Blue Economy Model" – BEM (Gunter Pauli, 2010) aims to boost sustainability, it is drawn on the functioning of natural ecosystems where nothing is wasted and everything is reused within a cascade process that transforms waste from one cycle into raw materials for another production cycle. The pursuit of this model fits in perfectly with the strategic actions taken by the EU to achieve the goals of the UN 2030 Agenda for Sustainable Development and the priorities announced with regard to the European Green Deal, the EU Biodiversity Strategy and the EU Farm to Fork Strategy. The European legislator allocated 6.6 billion euros for the Operational Programme of the European Maritime, Fisheries and Aquaculture Fund 2021-2027 (EMFAF) and declined all the priorities according to the BEM, as called for in the European Commission's communication of 17 May 2021 (EC, 2021).

How to better perform the BEM purposes is under question and calls for innovative solutions. Wave and tidal energy, algae production, the development of innovative fishing gear or the restoration of marine ecosystems will contribute to the creation of new green business and job opportunities in the blue economy. In fact, the need to foster the deployment of innovative tools has become a key issue in priority setting. For example, priority 3 ("*Enabling the growth of a sustainable blue economy and promoting the prosperity of coastal communities*") pays particular attention to dissemination of technological innovations to pursue sustainable fishing and the renewed interest in economic and social development models inspired by the principles of the Blue Economy. On the other hand, the fisheries and aquaculture sectors suffer from the low propensity of operators to change and introduce innovation due to numerous factors (Kumar et al., 2018). The analysis of both constraints and barriers to innovation adoption in fisheries and aquaculture is of paramount importance and has been mostly carried out through the lens of producers' perception of the complexity of innovation to be adopted. Perception is a concept belonging to the sphere of the "Self", which brings together a set of behavioural aspects such as motivation, emotion, relationships and cognition too (Markus and Kitayama, 2010). Perceptions are often portrayed as the means by which the farmer interprets reality and experiences, but it conceals much more multifaceted mechanisms. As Given (2008) points out, "P*erceptions are influenced by the embeddedness of the context in which they reside*". Studies have revealed the complexity of the adoption process which has led many authors to explore the interactions between fish farmers, the institutional context and innovation (Joffre et al., 2020). As a matter of fact, the concept of "*perceived complexity*", already applied to the agricultural sector fits perfectly to the fishery one (Welter, 2011; Vecchio et al., 2020a; 2022a; De Rosa et al. 2021) and is a context-related dimension. Drawn on Welter's (2011; 2018) definition of context, we identify two main elements: the "who" and the "where" context.

As far as the "who" context is concerned, age, education and company size represent the main variables to be considered. As clearly shown in literature, young people are generally more likely to adopt. In most cases, young entrepreneurs are also characterised by a higher educational background, which is well combined with a positive attitude towards innovation (Wetengere, 2011). However, Wetengere (2011) reported where older people are recognised as adopters, they experience much higher levels of adoption than younger people, who frequently stop at purchasing the tool without implementing it. Regarding the company's size, large businesses usually show a higher propensity to adopt, as they tend to diversify and have greater financial availability. While small companies, for which there is greater difficulty in accessing economic resources, are more likely to adopt where fishing is the predominant activity (Ndah et al., 2011; Kumar et al., 2021).

As far as "where" context is concerned, it involves not only territorial context, like urban or rural areas, but it includes the institutional context (both formal and informal) in which the innovation is embedded. The socio-cultural dynamics explored by Blythe et al. (2017) and Joffre et al., (2020) reveal the strong influence exerted by the information sources (e.g., neighbours, fellow farmers, cluster farmers, friends, extension services) from the phase of awareness of the existence of the innovation to the final decision to purchase. For example, belonging to an aquaculture cluster increases the possibility of adoption (Joffre et al., 2020). Moreover, culture convention and habits exert an influence in this process (Stanfield, 1999). Difficulty of accessing equipment, training and raw materials (feed, fries) are other factor impeding the innovation uptake. Finally, the support of local institutions can certainly create a fertile ground for anchoring innovation in a given context (Ndah et al., 2011, Kumar et al., 2018).

Within the “where” sphere also formal institutions play a role: the regulatory environment as well as the nature of the fishing sector have an impact on the acceptance and intensity of innovation (Kumar et al., 2018).

Briefly, all these interactions are used by scholars to understand farmers' views on the issue. Individuals develop an attitude towards adopting or not adopting a new practice or tool, as it expresses the way they perceive reality or an experience (Lewin, 1947). In addition, a greater likelihood of adopting aquaculture-related innovation is also linked to a “technically" positive point of the instrument, or in other words a perception that doing so will result in a relative advantage, such as the perceived increase in yield, cost efficiency and riskiness (Asche, 2008; Kumar et al., 2018; Kumar et al., 2021; Ulhaq et al., 2022).

Scholars have also emphasised how the choice of innovation is pursued when a “relative advantage” is perceived, with respect to the actual situation. (Obiero et al., 2019; Brugere et al., 2019) For instance, Brugere et al., 2020 report that the perceived effectiveness of innovation, intended as expected benefits, and the approval from other actors of the value chain are major drivers of innovation acceptance. Other positive perceptions associated with high levels of adoption include increases in trade flows and lower consumer prices and job creation (Asche 2008; Dey et al. 2006).

In everyday management, the diffusion of technologies that enable the breeding of better performing and genetically improved species or improvements in fish nutrition or disease pathology management are important conditions for creating an environment receptive to innovation in the aquaculture industry (Kumar and Engle, 2016).

All these factors potentially shape farmer's perception that translates into a positive or negative attitude towards the use of new tools in fisheries and aquaculture.

From previous consideration a gap in literature emerges, which concerns the consideration of just one layer of the aforementioned policy network. As a matter of fact, over the past decade, there is a growing recognition among experts that management of aquatic organisms, as well as the introduction of new technological tools, is about managing the actions of all the people who act on the resource (Hilborn, 2007); in particular, it is relevant to understand their views (Pedreschi et al., 2021).

Against this backdrop, analysing the perspective of those who contribute to setting up policy targets in the fishery sector, and thus work to provide fish farmers with the necessary tools to undertake a sustainable and circular transition, is instrumental in gaining a more comprehensive picture, as well as promoting a more effective diffusion of innovation. Therefore, this paper tries to provide an original contribution in literature by trying to analyse innovation adoption potential from the perspective of the policy network as before identified.

More precisely, the paper aims to understand the perceived complexity of the FAPN. Therefore, this article fits into the groove of understanding the behaviours, or rather the thoughts of FAPN facing the following research question: "*In your opinion, what does technological innovation in the fisheries and aquaculture represent?*".

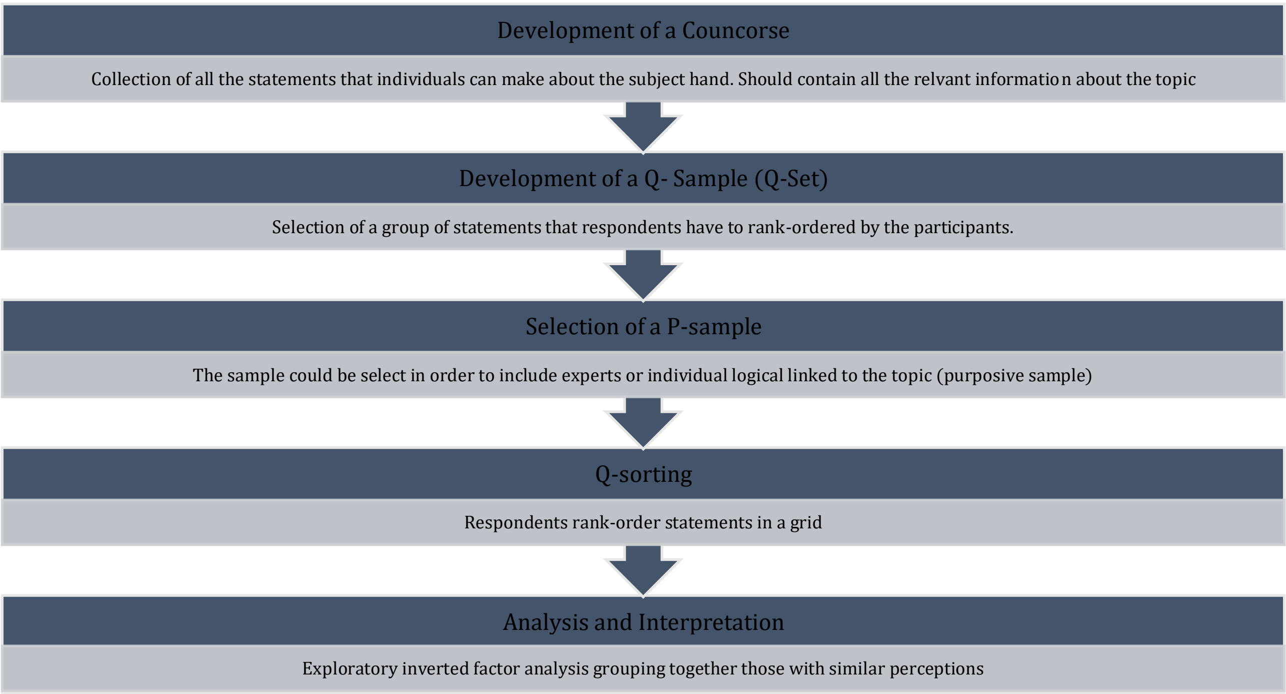
The present work is structured as follows: a first part defines the concept of perception and its role in the process of innovation in the fisheries and aquaculture, a second part describes the methodology proposed for the study of the policy network's point of view, the q methodology. The final part will be devoted to the results produced and the concluding reflections of the study.

2. Methods

Perceptions may not only be subjective, but may also express the thinking of a cultural group. Generally qualitative research is most interested in figuring out the complex dynamics of perception (Given, 2008). Qualitative methods have the potential to detect the nuances of a given behaviour and thus to observe individual variability, enriching the observed data. However, although they capture the peculiarities of human subjectivity, it is a less structured research that in most cases does not admit the reproducibility of the data and the procedure used in the studies. On the other hand, quantitative methods are both difficult to combine with the analysis of concepts in the sphere of the "Self" due to its scientific rigour and make these behaviours measurable implying the generalisation of the data (Durning, 1999). In this sense, hybrid methodologies, such as Q Methodology, represent a bridge between qualitative and qualitative research, which are able to overcome the weaknesses described (Brown, 1980). Mixing these approaches allows us to analyse the different faces of subjectivity and represent them in numbers, thus providing a hybrid tool useful to overcome the dichotomy between exclusively positivist or post-positivist approaches (Ellis et al., 2007).

Q methodology has been theorised in 1935 by Stephenson and was created with the aim of studying human subjectivity (Brown, 1980). It finds application from the medical and psychological sciences to the exploration of the propensity to innovate in agriculture (Vecchio et al., 2020b; Iofrida et al. 2018). This methodology is based on the fact that human subjectivity can be studied by ordering established statements on a topic within a forced distribution. More specifically, it consists of five steps (Figure 1).

Fig. 1 Steps in the Q methodology



Source: Vecchio et al., 2022b.

The first step concerns the formulation of statements, i.e. the "formation of the concourse". These are collected in focus groups with people who are interested in the topic. The second step, called the development of the "Q set", concerns the selection of the actual statements that will be used in the interview within all collected statements. For the selection of the items, items are usually traced back to common areas and then chosen. The statements usually range from 30 to 50, based on the need for dimensions to be explored and the number of subjects to be involved in the survey (Brown 1980), but less or more statements are also possible (Van Eeten 1998). The third stage is the selection of participants and is called the P-set, which is usually smaller than the Q-set (Brouwer, 1999), typically from 10 to 40 people. The fourth phase, called Q-sort, is the central phase of the method. Individuals are asked to sort the chosen statements within a grid, firstly according to the degree of agreement, disagreement and neutrality and secondly on the basis of the intensity of their choice (e.g. from -4 to +4). Each individual will then produce their Q sort and from the collection of all the data a data set will be produced. From this a reverse factor analysis (fifth stage) will be produced, as it will be carried out on the individuals (Q-sort) rather than on the set of variables to reduce the general information to common lines of thought. These points of view are called "discourses" and represent the output of the method.

Q-methodology allowed us to identify the prevailing discourses whose interpretation contributes to enrich the debate on the diffusion of technological tools in aquaculture, providing a new point of view on the subject useful to provide the policy maker with a tool to evaluate the efficiency of the actions implemented and can be used to rethink the policies for the diffusion of innovative tools.

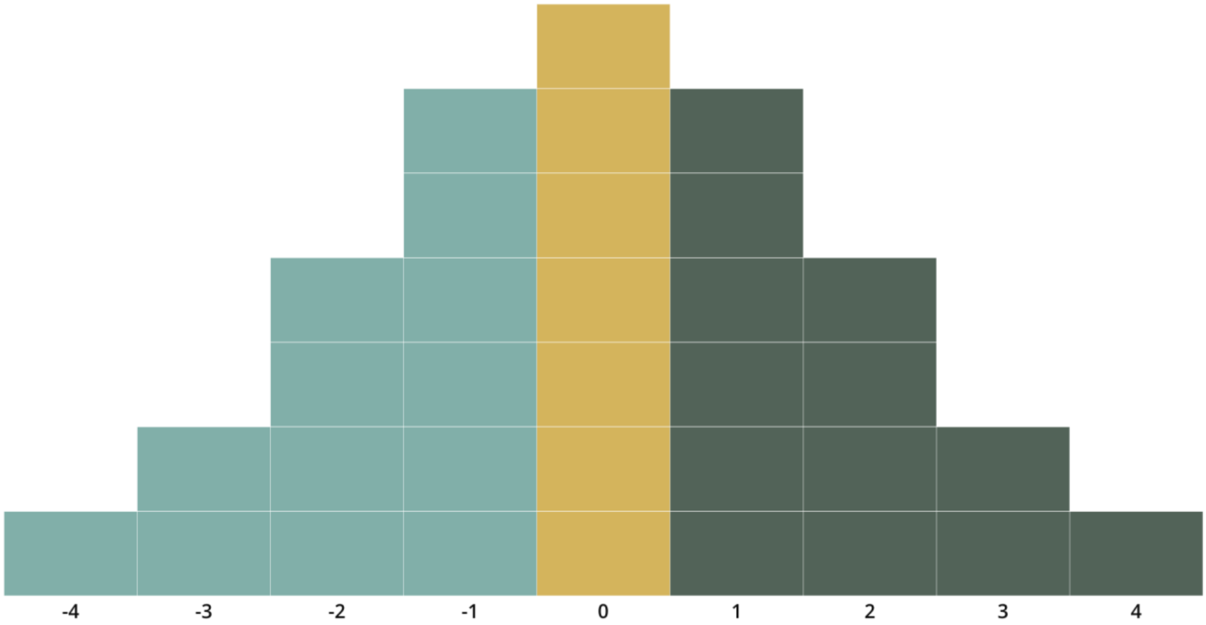
In order to conduct the empirical study, having a limited literature, the analysis was conducted in steps, in which in the first one a focus group was conducted with 6 experts in the field gathered from the world of academia and the world of institutions, characterised by diverse viewpoints on the meaning of technological innovation in the fisheries and aquaculture sectors (Zanoli et al., 2018).

In the Q methodology approach, the general opinion and issues on a topic represent the concourse (Brown, 1993). In the study, concourse was identified using a qualitative approach including the literature specifically addressing innovation in fisheries and aquaculture (Webler et al., 2009). In addition, a focus group was conducted by stimulating the respondents to discuss a set of statements collected in the literature. The aim of the study was to investigate the stakeholders' points of view regarding the introduction of innovative technologies in the aquaculture sector. For this reason, the group of stakeholders, in a sort of pilot study, helped us to delimit the dimensions to be investigated and choose the appropriate statements for each dimension. Based on results of literature review, focus group and stakeholders' interviews, the statements were classified in 5 main categories: economic sustainability, social sustainability, environmental sustainability, innovation complexity of use, innovation and marketing strategy (Hermelingmeier et al., 2017). To code the statements in the different categories, an interactive process among research group participants was applied. We fine tune concourse by eliminating items with equal meaning or those that included multiple concepts better explained in atomic items. The final concourse included 33 statements (balanced among categories and characterised by pros and cons positions). As Brown (1993) suggests, statements were presented using ordinary language and spelling the same as the original.

To better calibrate the statements to be used in the q-sort process within the fixed quasi normal distribution (Figure 2), the focus group was conducted by stimulating the respondents to discuss a set of statements, our concourse, in order to better delineate the choice of items to be administered. At the end of the focus group a qualitative analysis was carried out in which the most important dimensions were extracted, the result of which was to evaluate the introduction of innovations with respect to their impact, social, economic and environmental, and with respect to the complexity of use. For this purpose, 33 statements were defined to be added to the Q-set.

The P-set consists of 21 experts in the fisheries and aquaculture field. In the process of researching the components, therefore, all those actors belonging to the policy network were identified, considering all three layers, thus interviewing policy makers and directors of agencies in the sector, members of trade associations and POs, and finally also civil society actors, such as professors and researchers and citizens who by their act of consuming give information and express opinions. The number is consistent based on the literature (Watts and Stenner, 2012). Inverse factor analysis, applied on the 21 Q-sorts produced, subsequently produced the discourses of the study.

Fig. 2 Example Fixed Quasi-Normal Distribution. Ranking values range from -4, through ‘zero’, to +4. A total of 33 items could be accommodated in the distribution illustrated.



All analyses were performed using SPSS v.28 and Qmethodsoftware.

3. Results

The Q-Methodology is applied to identify common factors between the views of different individuals on the topic of innovation in the fisheries and aquaculture field.

The intercorrelation matrix was calculated using the centroid procedure by rotating the solution using the varimax criterion (Watts and Stenner, 2012). Afterwards, the criteria for selecting the factors were determined, starting with the factors with eigenvalues greater than one, but only four were investigated according to the interpretability criteria. The characteristics of the factors are represented in Table 1.

TABLE 1 Factor characteristics

	factor 1	factor 2	factor 3	factor 4

No. of Defining Variables	10	4	5	2
Avg. Rel. Coef.	0.8	0.8	0.8	0.8
Composite Reliability	0.97561	0.94118	0.95238	0.88889
S.E. of Factor Z-scores	0.157	0.242	0.218	0.334

The factor scores are weighted averages (Z-scores) of the values assigned to each instruction by the people who defined it. To make the results easier to understand, the Z-scores in Table 2 have been changed to the values of the original scale [-4 to +4]. The table illustrates the relative importance of each statement in each of the four groups that emerged from the factor analysis, and a quick glance at the table reveals the contrasts and similarities between the various points of view.

TABLE 2 Statements belonging to the Q-set.

Statement	Factor 1 Rank	Factor 2 Rank	Factor 3 Rank	Factor 4 Rank
1. The use of new technological tools in aquaculture to be more sustainable towards the environment	4	2	0	-2
2. A practice that is badly adapted to the specificities of individual farms	-2	2	-1	0
3. The use of new technological tools that create damage to the environment	-3	-2	0	-1
4. The use of new technological tools to monitor adverse climatic events	0	1	4	-1
5. The possibility of aquaculture farming without altering marine spaces	0	3	1	-2
6. A practice too complex for the knowledge/experience of fish farmers	-1	1	-1	1
7. A technology easy to understand	-1	-2	-4	1
8. A technology easy to use technically	0	-1	-3	0
9. The use of new technological tools in aquaculture requiring organisational and structural adaptations difficult to implement	0	0	0	0

10. A technology that involves only young fish farmers	-1	-4	1	-2
11.The use of new technological tools in aquaculture to reduce production costs	2	-1	1	-1
The use of new technological tools in aquaculture to increase yields	1	-3	2	3
13.A practice that is not sustainable without economic support (e.g. bank loan, etc.)	0	4	1	-3
14.The use of new technological tools in aquaculture that partly replaces labour	0	-3	1	0
15.A technology suitable for large farms	-1	0	2	3
16. A technology already widespread in Italian territories	-2	-1	-1	-4
17.A practice that makes work easier to carry out	1	-2	3	4
18.A new practice/technology that shows results in the long term	0	2	0	1
19.A technology to improve the working conditions of the employees in the company	1	-1	0	1
20. A strategy that can only be pursued through the development of an environment	3	3	0	2

that sees the collaboration of research institutions, the territory and the aquaculture world				
21. A new technology to support farm management that can only be used by sharing risks and benefits with a group of fish farmers	-1	0	3	0
22. A simple purchase of machinery	-2	-1	-2	2
23. A useless tool for the aquaculture sector	-4	-1	-1	0
24. Useful tools for brand-identity of companies	-1	1	2	1
25. Technological tools useful only in the processing or marketing phases	-2	-2	-1	2
26. The use of technology is linked to knowing how to use and continuously exchange data and information	1	1	1	-1
27.Technology that does not allow the recruitment of new employees	-3	1	2	0
28. Technology that improves animal welfare conditions increases consumer acceptability	1	0	-2	-2
Technology allows for greater use of renewable energy sources in the production cycle.	1	2	-2	-1

30. Technology helps increase levels of biosecurity	2	0	0	-1
31. Technology helps make the breeding of indigenous species economically and environmentally sustainable	2	0	-2	-3
32. Technological innovation helps to improve the organisation of the fish chain	3	0	-1	1
33. Technological innovation improves the position of the producer in the supply chain	2	1	-3	2

The four prevailing thoughts that the analysis highlighted are as follows:

- **Discourse 1 A key to achieving sustainability and improved competitiveness of supply chain**

The first discourse includes members who most support the potential of the technology for the fisheries and aquaculture sectors. Members that fall into this group share the thought that technological innovation represents a way to boost both the environmental and economic sustainability of production. Among benefits, they emphasise the potential of reducing the impact on the environment and the risks to human health, and finally, the possibility of reducing production costs and making the breeding of native species economically sustainable. The adoption of these tools also has repercussions on the organisation of the value chain itself, as it improves the organisation and the bargaining power of producers. The importance of developing an environment that involves the collaboration of research institutions, the territory and the actors of the fish value chain is the only possible way for the effectiveness of the transfer of innovation in the context. In this sense, they believe that by developing an environment conducive to innovation, it can be well applied to the specificities of individual companies.

- **Discourse 2 A capital-intensive practice beneficial only to the environment**

The common thought of these members is that the new technologies allow producers to be less impactful towards the environment, and in particular to breed without altering marine spaces. They even believe that technology allows for greater use of renewable energy sources in the production cycle. In respect of the socio-organisational dimensions, they believe that adoption does not lead to the replacement of labour, the improvement of working conditions or the simplification of work; while for the economic dimension, they argue that technology does not lead to maximising yields. The barrier they underline is that adoption requires a considerable economic effort, and therefore cannot be pursued without external support, given that the results are, for them, achievable in the long term. Also, in this case, the transfer of innovation is seen as a strategy that can be pursued only through the development of an environment that involves the participation of context-related stakeholders. Finally, they consider that adoption is not only a prerogative of young people, rather they stress more the limit of compatibility with business specifies.

- **Discourse 3 A technically complex tool for managing the risks of adverse climate events, but acceptable if shared**

Those who belong to this discourse slightly support the potential of adopting technological innovations in fisheries and aquaculture. They clearly believe that the application of these tools is linked to the business reality, declaring themselves neutral on the importance of creating an institutional environment receptive to welcoming the diffusion of these technologies. In fact, it is the only group that disagrees with the statement "*technological innovation serves to improve the* *organisation of the fish supply chain*". They recognize their application mainly for monitoring adverse climate events; while in a minority, economic and social benefits are underlined such as the possibility of simplifying work, increasing yields and improving company brand identity. A strong characteristic of this group is the idea that technology is difficult to understand and use technically, justified by the perception that for them it is a tool only for young people. However, the role of collective action takes on an important value from the perspective of these people, who think that these tools can only be used by sharing risks, benefits and knowledge with a group of fish farmers.

- **Discourse 4 The purchase of useful tools to increase production yields and simplify work**

People who fall into this group are those who believe that the application of technological innovation can lead to making work easier and lead to increased yields. In line with this thinking, they believe that this technology is particularly suited to large companies, which often tend to combine manual labour with automation to optimise operations. The vision they have is most focused on the role of technology that will improve productivity. It is precisely because of the greater ability of large firms to absorb higher costs that they associate a more receptive environment with the introduction of technology; in fact, they do not recognize the economic barrier as primary in this regard. Coherently with this perspective, they support technology's application in the processing and commercialization phases. Characteristic of this discourse is the idea that technology does not exert effects on improving the environmental and economic sustainability performance of the breeding activity.

4. Discussion

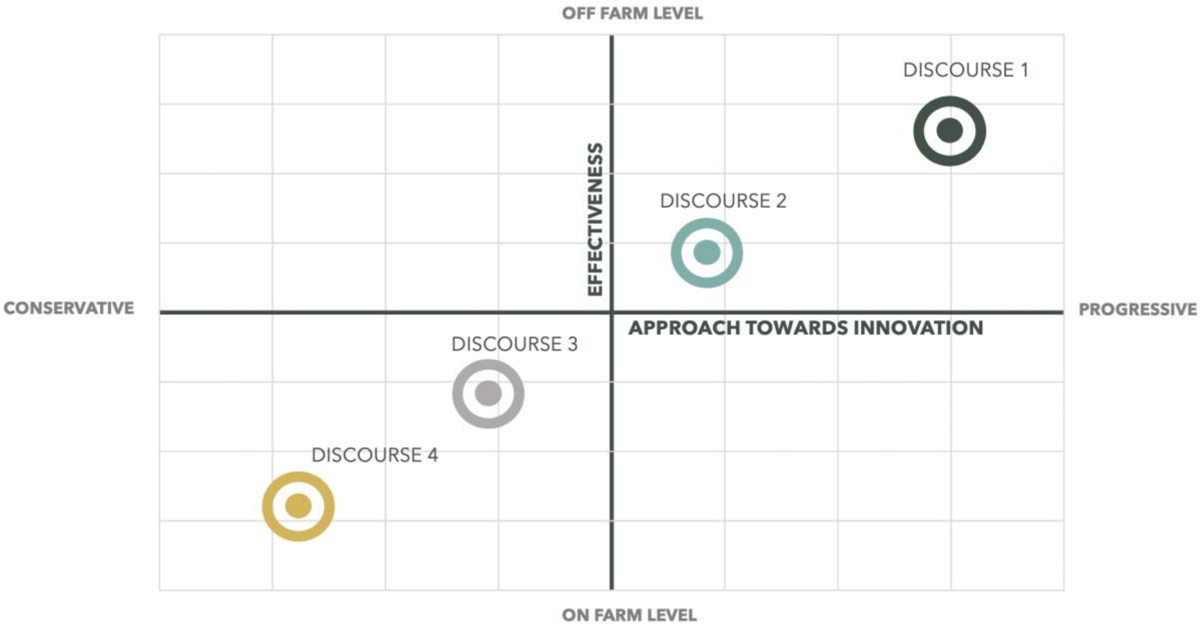
The study of the diffusion of technological tools for the fish sector is not extensive (Kumar et al., 2018), and mainly delves into the complexity of adopting from the perspective of producers. However, recent studies are emphasising that the goal of effectively anchoring innovation to a given context can be pursued through the development of a receptive environment, engaging research institutions, actors involved in the fish value chain and institutions involved in strategic decisions for the sector (Joffre al., 2020; Greaker et al., 2020; Brugere et al., 2021; Cascante et al., 2022). It is for this reason that it is necessary to understand the point of view of the articulated set of actors making up what we have identified here as a policy network, or in other words the experts involved in the political processes of the fisheries and aquaculture sectors.

It is through the Q-methodology that this study has captured main thoughts regarding the anchoring mechanisms of the innovation processes in the fisheries sector. By making human subjectivity measurable, this method draws on the strengths of both qualitative and quantitative methods and applications on the primary sector are now becoming more widespread (Davies and Hodge, 2007; Iofrida et al., 2018; Vecchio et al., 2020c).

Four main discourses emerged from the analysis: the first discourse represents those who strongly support the potential of innovation, which can not only help make the breeding of native species economically and environmentally sustainable, but also improve the bargaining power of the weakest links in the chain. The second thought recognises in technology the potential to reduce the impact on the environment and even to embrace a logic of a circular economy, arguing that it can increase the introduction of renewable energy in the sector. According to their thinking, innovation has been seen as a high capital-intensive practice that could be adopted only with external financial support. The third one sees innovation as a mere tool, difficult to accept due to its technical complexity from the point of view of understanding and use. In fact, those who share this view are the only ones who think that technology is only for young people. For them the application is linked to the possibility of predicting adverse climatic events and in a certain way as a sort of "risk management" tool. In this sense, and consistent with the literature on risk management for the primary sector (Ulhaq et al., 2022), they intend to adopt these tools only if shared. Similarly, participation in mutual funds for the fish sector implies risk sharing for the prediction of adverse climate events (Vecchio et al., 2022c). The fourth embraces a more industrial vision, emphasising how technological progress can boost productivity by simplifying work. Within this discourse, no effect of innovation on producing social or environmental benefits emerged; rather, the economic benefits of adoption were pointed out, but only, within corporate governance. It is in this group that it is sustained as a tool that can only be adopted by large companies. Those who share this thinking are the only ones who think that technology is easy to understand technically.

What emerges is that the 4 discourses differ mainly for two aspects: the approach to innovation and the perceived effectiveness in terms of expected benefits (on-farm, off-farm level) (Figure 3). In particular, we define effectiveness at "off farm level" as those expected benefits produced by innovation beyond fish-farmers' control.

FIGURE 3 Discourse positioning diagram based on their attitude toward innovation and perceived effectiveness.



On the basis of previous considerations, it is possible to identify two main approaches to innovation:

1. The first, is the **"progressive approach towards innovation"**, taken by the first and second discourses. This approach is taken by all those who admit the effectiveness of innovation at company level and think about the broader potential that these new tools can exert, particularly in achieving sustainability goals and reducing the impact on the environment (off-farm level). In this sense, thinking also of technological innovation not as a tool but from a more systemic perspective capable of producing benefits, in terms of competitiveness, also to the whole value chain. These two discourses support the importance of developing an environment receptive to innovation, encouraging information exchange and learning processes within the policy network. Following this vision, discourse 1 could represent the perspective of "Strong Progressives", while discourse 2 of "Moderate progressives" experts belonging to the policy network.
2. The second is the **"conservative approach towards innovation"** and mainly concerns the thinking of discourses 3 and 4. In particular, innovation is seen merely as a tool, whose

potential lies solely in the business perspective. In particular, it is discourse 4 that emphasises the possibility of increasing productivity and simplifying work by combining manual work and automation at company level, while Group 3 recognises it as an environmental risk management tool. In this sense, discourse 3 could represent the perspective of "Moderate Conservatives", while discourse 4 of "Strong Conservatives" experts belonging to the policy network.

The two approaches may reveal a different conceptualisation of innovation. The conservative approach perceives it mainly as a "*business innovation*", i.e. of a commercial nature, since, according to Sawhney et al. (2006) and Charatsari et al., (2022) it is oriented to satisfy market needs and give a relative advantage to those who adopt it. This could be confirmed by the strongly utilitarian view of the tool they have, as a means of achieving business profit. The proactive approach, on the other hand, takes a broader view of innovation, with the aim for some of ensuring positive externalities on the fish value chain, and for others on the environment.

The points of view also have also other discriminating elements or elements of contact.

All 4 discourses remained neutral on the fact that the use of new technological tools in aquaculture requires organisational and structural adaptations that are difficult to implement, instead emphasised by scholars (e.g Brugere et al., 2020) from the point of view of fish producers. In any case, discourses 1, 3 and 4 think that it can simplify the everyday work routine. Similarly, the views (-1 to 1) about whether innovation is too complex for the knowledge/experience of fish farmers or whether it can improve the working conditions of employees on the farm were fairly aligned. However, discourse 1 is the only one that disagrees that the adoption of innovation prevents the hiring of new employees. Furthermore, discourses 1, 3 and 4 all agreed that the use of new technological tools in fisheries and aquaculture will lead to economic benefits such as increased yields. Finally, Discourses 1, 2 and 3 agreed that adoption will help current production systems to reduce their impact on the environment, while discourse 4 expressed the contrary.

4. Conclusion

The results of our analysis could offer solutions but also new challenges to be explored. First of all, the Q methodology proved to be an adequate method to represent in numbers the field of the cognitive sphere, which has mainly been analysed with qualitative methods (Durning, 1999, Ahmed and Haq, 2019). In spite of the limits linked to the representativeness of the sample that can be analysed, given the maximum size that can be interviewed (Watts and Stenner, 2012), the tool is well suited to delve into the complex thoughts coming from groups of stakeholders (Van Exel and De Graaf, 2005), that in this paper are represented by those of fisheries and aquaculture policy network. This could be a useful basis to provide new insights to policy makers, giving them new perspectives to rethink the policies put in place to pursue the objective set in the new EMFAF of strong diffusion of innovative technologies.

The two macro perspectives identified give rise to two different thoughts. If on the one hand, for conservatives, technological innovation represents only a process of modernisation of the organisation, therefore adoption is only a purchasing process; on the other hand, for progressives something more. These different perceptions could be taken into consideration by policy makers, who should draw different paths to support innovation. In this sense, this study highlights the need to take more account of the often-neglected point of view of experts of the policy networks in order to match the effectiveness of innovation policy with the needs of the fisheries and aquaculture sectors. These issues become crucial at a time of great uncertainty, in the Knightian sense of the term, with a sector such as aquaculture directly involved in the ecological transition but facing one of the most important crises after a two-year period marked first by the COVID-19 pandemic crisis, then by the war between

Russia and Ukraine, not forgetting climate change, which during the Glasgow Cop26 was renamed the climate crisis, directly affecting the sector. In times dominated by uncertainty, the European Commission's challenge to strengthen the role of knowledge and information becomes a priority and could be the key to the development of a sector that is key to ensuring food security that has now returned to the centre of the international debate. The EU's Green Deal and the European long -term vision for future economic and social development pointed to technological innovation as the solution to facilitate the sustainable transition of the agri-food sector (De Castro et al. 2020). In this scenario, the study proposes a new way of analysing the cognitive sphere of the experts and a new tool to be used by policy makers to improve the effectiveness of the measures written to put into practice the indications coming from the political direction of the European Commission. Moreover, it implements a new approach to identify scalable and differentiated solutions to favour the diffusion of technological innovations for the two dominant thoughts. In this way, the realisation of European renewal relies heavily on the advancement of responsible research and innovation (RRI), i.e. adoption of innovation is related to the “responsibility” to produce ethical and social values as well as sustainability, avoiding negative effects in the future of the fisheries and aquaculture sectors. In this study, the discourses could help the policy network to formulate “Responsible” policies for these sectors. A better understanding is needed on the one hand to enrich the framework for innovation uptake in fisheries and aquaculture and on the other hand, to support an effective path of responsible innovation. Future research will focus on the study of innovation in aquaculture and fisheries from the perspective of RRI.

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Third chapter

Title page

From AKAP to AKAIE model to study technological innovation's uptake in the aquaculture sector

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Abstract

The purpose of this study is to explore the adoption of innovation in the aquaculture sector through the Awareness Knowledge Adoption Implementation Effectiveness (AKAIE) sequence. The AKAIE is an extension of the Awareness Knowledge Adoption Product (AKAP) model in order to better investigate the post-adoption phases. Using the "*Implementation*" and "*Effectiveness*" phases, this study aims to further the understanding of both the different levels of adoption and the impact of innovation in terms of environmental, economic and social benefits produced. The proposed sequence is contextualised in the light of the multidimensional scenario of on-farm and off-farm factors acting alongside the adoption of new technologies in the aquaculture sector. In this paper, the perspective of aquaculturists is represented with the concept of perceived complexity as the central node of the adoption process. The proposed tool could support policy makers in understanding and disseminating innovation in aquaculture.

Keywords: aquaculture; innovation; technology; AKAP model, AKAIE model; adoption process.

1. Introduction

The growing pressure for food and nutrition security and for more efficient use of natural resources imposes increasingly sustainable trajectories for agri-food systems. Aquaculture has experienced the fastest expansion among worldwide food producing sectors over the past 30 years[1] and is estimated to provide 106 million tonnes of the 202 million tonnes of aquatic animals produced globally in 2030[2]. Over the past two decades, institutions and scientists have supported actions for sustainable intensification to combat negative externalities associated with aquaculture[3,4,5], which are related to combat the overexploitation of natural stocks to produce fish meal and oils, emergence of new diseases in wildlife species, chemical and nutrient pollution, and effects on marine and coastal habitat or inland uses of land and water[6].

New technological innovations (TIs) have been proposed in aquaculture to address the reduction of negative externalities and global sustainability challenges. In February 2021, the Food and Agriculture Organization's (FAO) Thirty-Fourth Session on the Committee on Fisheries released a report[7] on the fish industry's contribution to sustainable development goals, emphasising how the diffusion of innovation in fisheries and aquaculture could accelerate the transition of systems toward the 2030 targets. The role of innovation is emphasised as central to the achievement of SDG 14 "*Life Below Water*" to both guarantee food and nutritional security and to support the transition towards sustainable and circular models of the aquaculture sector. For example, the role TIs can play in reducing poverty (SDG1 "*No poverty*"), food insecurity (SDG2 "*Zero hunger*"), inequalities (SDG 5 "*Gender Equality*"; SDG 10 "*Reduced Inequalities*") and in ensuring decent working conditions (SDG 8 "*Decent Work and Economic Growth*") allowing these activities to provide economic resilience is discussed. As a result, the diffusion of innovations could facilitate cooperation between the public and private sectors, companies, research bodies, and policy networks[8].

The most innovative management of practices is now required at the European level to support the challenges of predicted climate change, especially for fisheries, and for monitoring environmental conditions and the performance of aquaculture activities; supporting the policy network in implementing actions for more sustainable production and consumption (SDG 12 "*Responsible consumption and production*"; SDG 13 "*Climate Action*").

The European Green Deal strategy also supports the essential role of research and innovation in driving the technical and ecological transition of agri-food systems. In particular, the Farm to Fork (FTF) strategy has set ambitious goals for the sustainability, competitiveness and resilience of European aquaculture, which is considered fundamental to achieving the transition of the entire primary sector.

European countries are reviewing their actions (i.e., legislative frameworks, funding) in light of the FTF strategy. In particular, the objectives of the European strategies have conditioned the new Common Fisheries Policy (CFP), translating this new trajectory into new measures of the European Maritime, Fisheries and Aquaculture Fund (EMFAF), focused foremost on the development of the aquaculture sector. Both new funding flows supported by the EMFAF (2021-2027) with a budget of 6.108 million Euros and ecological schemes plan to promote more sustainable practices through the CFP and accelerate the transition to respect the roadmap of European Strategies on climate and environment. Finally, research and innovation on sustainable aquaculture is a priority for Horizon Europe, the European framework program for research and innovation.

The reasons why innovation is entrusted with driving this transformation can be found in the definition provided by Mbabu and Hall[9]: "*innovation is the new use of existing or new ideas or the combination of ideas that have social or economic significance*" to respond to ecological, social and institutional changes which are implied as agri-food systems. Numerous technological and non-technological innovations have been recognised as driving forces able to combine the growth and social and environmental issues of aquaculture production systems[10]. Technological advances include breeding systems, feeds, information and communication technologies, while non-technological includes improved regulatory frameworks, organizational structures, and market standards[11,12].

The aim of this paper is to provide a new model for interpreting the transfer of TIs in aquaculture and their implementation based on different levels of analysis, from an extra-farm context to an intra-farm context to consider the characteristics of the technology itself. The combination of TIs and aquaculture practices can offer great opportunities to the sector, when applied to breeding and genetic techniques, disease management, feeding processes and sustainable production systems[13,14,15]. In this sense, technological innovation could help to monitor processes and resolve production risks[16].

Previous studies highlighted this potential not only at a production level but also a broader level. do Amaral et al.[17(p.184)] state that "*a low level of technology adoption reflects on less efficient production systems*"; while Wetengere[18 (p.34)] adds that "*the contribution of fish farming to household nutrition and income security depends more on the level of technology adopted*".

Studies have traced the adoption of innovation in aquaculture[19,20], mainly on a firm level[21] applied to freshwater [22,23,24,25], marine [15,16] and shrimp farming[19,26] primarily conducted in Asia and Africa.

Adoption is defined as a complex framework[22,27] especially when aligned with the socio-economic dynamics of the aquaculture production system[20,28,29]. Complexity stems from numerous factors affecting the propensity to adopt[19]. Kumar et al.[27] conducted an in-depth review for this in aquaculture, indicating it as very recent and underdeveloped[19,30]. In fact, the attitude to innovate has been primarily explored for the agricultural field since Ryan and Gross[31] and Griliches[32] discussed the barriers and drivers of adoption[33,34] by investigating how structural (on-farm factors) and institutional (off-farm factors) aspects can generate a perceived complexity and, therefore, significantly influence potential adoption[35].

Furthermore, there is a great heterogeneity of studies, some have investigated the determinants of adoption during the entire decision-making process, from awareness to the phases of developing interest and evaluation of TIs, to those of experimentation and adoption according to the Innovation Diffusion Theory (IDT) by Rogers[36]. While, others have focused mainly on concerns related to the final decision to purchase the innovation. At the same time, a deficiency exists in the assessment of the post-adoption phases and the eventual implementation of innovation between studies, which results in difficulty in distinguishing a purchase choice from a partial adoption or more intensive levels of adoption. Furthermore, scholars revealed a plurality of visions when assessing the impacts, or in other words the effectiveness, of technological innovation on the performance of the aquaculture sector, mostly due to the complexity of defining unambiguous parameters to estimate its effects. From this scenario, some concerns need to be mentioned:

i) Current studies in aquaculture on the uptake of new technologies, implementation and effectiveness are still lacking and most have been performed at the farm level in developing countries[19,20,37];

ii) Further investigation is rewired in order to understand the reasons for the low or partial adoption of TIs at the farm level and the influence of context dynamics whereby innovation is applied[13].

The present study intends to investigate the adoption of TIs in aquaculture and the intensity of uptake at the farm level after the first purchase. On one hand it is relevant to discern bottlenecks of adoption of innovation, and on the other hand, it is necessary to highlight drivers preventing a greater inclusion in farms.

To further the post-adoption phases, we intend to analyse the decision-making process through an implemented Awareness Knowledge Adoption Product (AKAP) model, which also incorporates the

“*Implementation*” and “*Effectiveness*” phases, theorising the *Awareness Knowledge Adoption Implementation Effectiveness* (AKAIE) model.

The study will be structured as follows: section 2 will discuss the AKAIE model. The on-farm, off-farm factors and perception spheres influencing uptake will be illustrated to contextualise the proposing sequence. Finally, section 3 provides a discussion of topics, conclusions and policy implications.

2. A holistic approach from AKAP to AKAIE model

The AKAP model was theorised by Evenson in 1997[38]. Over time, the AKAP model has been used to study impacts of alternative extension approaches in agriculture[39]. Today, this sequence has been approached to analyse the adoption process to help policy makers in developing lines of action to support innovation in agriculture[40,41]. Vecchio et al.[41] reported that this sequence aligned perfectly with the multidimensional nature of the adoption process and with the systemic character which the concept of innovation process is increasingly assuming.

This model consists of four phases[38] (Fig.1). The first phase is the “*farmers' awareness*”, in which the individual becomes aware of the existence of innovation. It is only later that, after developing interest and experience, the individual decides to acquire more information and gain knowledge, which is represented by the second step, namely “*farmers' knowledge, through testing and experimenting*”. In the third phase, called "*farmers' adoption of technology practices*", the individual decides to adopt after having made assessments and possibly, having experienced the innovative practice.

Finally, the last phase considers “*changes in farmers' productivity*” by following adoption, as conceptualised by Evenson[38] as the “*added value of goods produced from a given set of inputs*”.

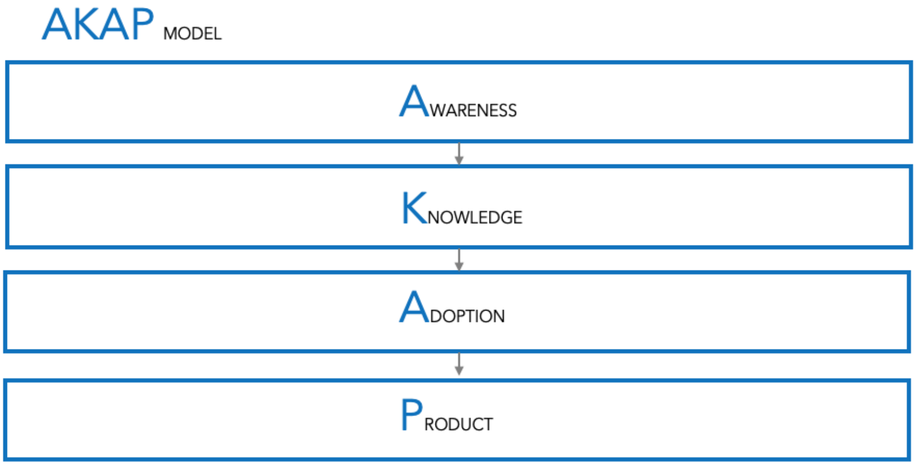

Fig. 1 The AKAP model, according to Evenson (1997).

The present paper aims to study TIs' adoption in aquaculture by proposing an extended AKAP model which is built to further post-adoption phases, where adoption is expressed as the decision to first use/first purchase a new technology and consider the "Implementation" and "*Effectiveness*" as post-adoption phases (Fig. 2). This paper introduces into the sequence "*Implementation*", understood as the phase in which the farmers engage in a higher level of adoption than the initial purchase, and "*Effectiveness*", understood as the phase in which concrete benefits from the adoption of ITs can be experienced. The AKAIE sequence suggests the importance of considering the post-adoption phases. In the case of a technological tool, the adoption process requires the evaluation of both the post-adoption phases of implementation of the technology in business practices over time (i.e., involvement, capacity of use) and, consequently, the impact of these actions. During the adoption of innovation, it is necessary to verify whether the initial adoption (i.e., the purchase) is likely to result in a partial adoption if the purchase is not followed by an "*Implementation*" phase or if the results are not very effective ("*Effectiveness*").

First, the model proposes to interpret the phase of the "*Product*" as the "*Effectiveness*" of the innovation. There are few empirical studies that have investigated the post-adoption phase and specifically the impacts of innovation on the food value chain. From the existing studies, most have proposed to explore the impact of innovation in agriculture through productivity measurement. Fewer studies have emphasised improved input/output ratios resulting from precision management of temporal-spatial soil variability[42]. Today, there is an increasing need for additional studies demonstrating the benefits and performance, not just economic, of the food supply chain. The need to extend the scope of investigation has long been identified in the literature on Small and Medium-sized Enterprise (SME) performance[43,44] questioning the concept of innovation effectiveness. Empirical evidence has supported this view, focusing on non-financial indicators when assessing innovation effectiveness in SMEs[45]. For these reasons, we believe that interpreting the "Product" phase as "*Effectiveness*" could be functional to fully consider the result of the application of innovation in terms of economic, social and environmental benefits produced.

Second, the model includes the "*Implementation*" phase. In most studies, adoption was considered only as use/non-use or purchase/non-purchase. However, criticisms have been made for many years at the definition of adoption. According to Black[46 (p.356-361)] "*Proper measurement extends beyond the initial decision and requires the addition of the time or use dimension of the innovation",* also adding that *"Dichotomous operationalization can be significant when examining discontinuous innovations, but even in these cases, the evaluative processes or confirmation phase and their potentially important effects on subsequent actions are overlooked".* In our opinion, more studies on post-adoption phases are needed to evaluate different levels of adoption of TIs [47].

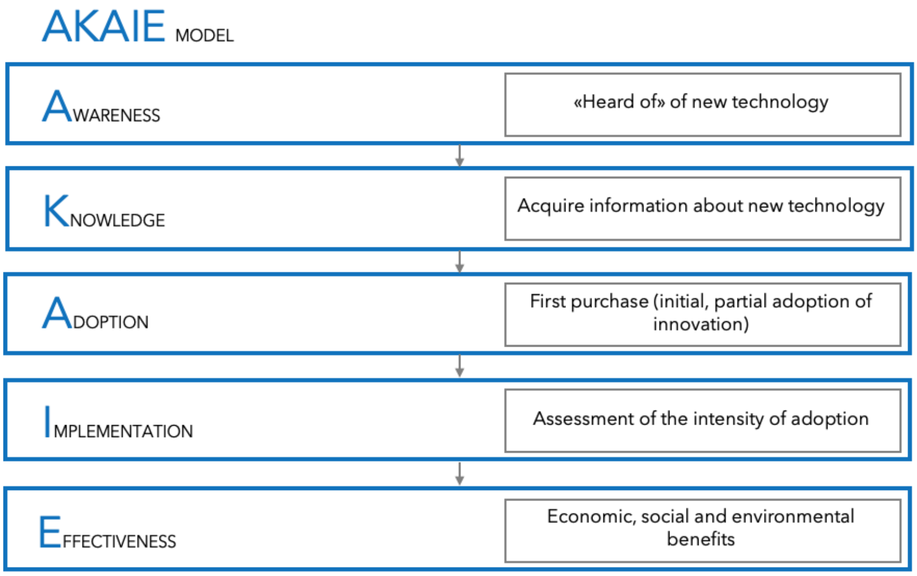

Fig. 2 The Awareness Knowledge Adoption Implementation Effectiveness (AKAIE) model (own elaboration).

Phase 1– AWARENESS

The first stage is "*Awareness*", or in other words "*having heard about*" a technology for the first time[48]. This is a prerequisite for adoption[49] and corresponds to the moment in which the individual becomes aware that a technology exists[50]. Among innovations, some researchers[e.g.,13,14,15,51] have attempted to discern the available technologies in aquaculture farming into several areas: breeding and genetic technics, biosecurity and disease management, nutrition and feeding technologies and sustainable production systems. In the genetics field, the use of improved stocks is proposed to increase farm productivity, ensuring farm efficiency by controlling cost items mainly related to feeding or to the control of diseases. In the feed sector, alternative diets to fishmeal are proposed, based on plants and with low environmental impact. For the control of diseases, selective reproduction, improved management of feeding or hygiene techniques and new diagnostic tools or monitoring systems are employed. In contrast, more sustainable farming systems include recirculation aquaculture systems, biofloc technologies, and integrated systems[52].

Antonucci and Costa[53 (p.1)] reviewed some TIs that can be used in the field of precision aquaculture (PA), including the "*computer vision for animal monitoring, environmental monitoring tools and sensor networks, robotics and finally data interpretation and decision tools (e.g., Internet of Things and decision support systems)*".

In a study by Føre et al.[54] on intensive salmon farming, a clearer definition of PA was provided by imagining the application of these tools to the farming cycle. Cage farming can be seen as a series of cyclic operations that produce bio-responses in different phases. The first phase is where the bio-responses of the fish are observed inside the cages ("Observation"), thus, making use of tools such as smart sensors and online monitoring instruments (e.g., GPS, echo sounder, remote sensing). The second phase occurs when the responses are interpreted ("Interpretation") through predictive models or simulation systems, which provides the answers to make decisions ("Decision") through the use of artificial intelligence and decision support systems on specific actions ("Action"). It is in the latter phase that specific actions are implemented to integrate automated operations and innovative tools to achieve certain objectives and, more generally, to generalise the expected biological response of the salmon.

Finally, multi-actor technologies such as innovative platforms and business incubators have also been applied to aquaculture[10,55]. More systemic approaches to innovation are increasingly required to better climb different levels of complexity (technological, socio-cultural, institutional, environmental aspects of the sector) and to stimulate innovation for sustainable aquaculture by promoting learning processes among actors and improving the ability to anticipate changes for the sector[51].

More generally, in the agricultural field the concept of the innovation process has been the subject of a major evolution in thinking that has increasingly characterised its complexity and systemic nature, as opposed to linear processes, in which innovation was channelled from science to end users[56]. As a result of this evolution, the structure of knowledge services created for the agricultural sector now supports systems such as the Agricultural Knowledge Innovation System (AKIS), which encourages systemic visions of innovation processes as well as an interactive approach in which social learning is an important lever for the diffusion of innovation. This vision, which has been widely supported by common agricultural policies since the 1990s, has barely been explored for the aquaculture sector over the last decades and, only recently, experiences such as innovation platform and business incubators[1] have invested in knowledge to provide innovative solutions for the sustainable transition of aquaculture farms[10,51]

Phase 2– KNOWLEDGE

The second phase is "Knowledge", which according to Evenson[38] (p.46) "*requires awareness, experience, observation, and the critical ability to evaluate data and evidence".* Once the individual is aware about innovation, they seek to determine "*how and why it works*" [57]. Two types of knowledge have been distinguished:

i) "*How-to-knowledge*" or in other words the individual learns how the technology technically works to ensure that it will be used at the expected level;

ii) "*Principles-knowledge*" to understand why an innovation should be applied and how it could be integrated into everyday practices.

[1]European Aquaculture Technology and Innovation Platform (https://eatip.eu); Hatch blue (https://www.hatch.blue); Maine aquaculture innovation centre (https://umaine.edu/ cooperative-aquaculture/business-incubation/); WorldFish Incubator http://www. worldfishcenter.org/content/worldfish-incubator; New Jersey aquaculture innovation centre (http://aic.rutgers.edu/);

According to Rogers[57] "*how-to-knowledge*" is a prerequisite for adoption. However, having a proper "*how-to-knowledge*" does not indicate that farmers will adopt that technology; their attitude also greatly influences this choice. It is also relevant to note that adopting without the "*principles-knowledge*" can lead to discontinuous forms of adoption or even interruption.

Phase 3- ADOPTION

The adoption processes have primarily been described as sub-processes of the diffusion of innovation[58]. Otherwise, "Adoption" has been approached at a theoretical level from different perspectives in sociological, economic and even, marketing fields[59].

The *economic approach* focused on the individual's rational choice that depends on factors that normally act on the purchase decision. Through this approach it is argued that the potential adopter is a rational individual who weighs the benefits and costs before buying a new technology. The first study that supported this approach was Griliches[32] with the first empirical work on the spread of hybrid corn in the United States, which demonstrated how economic factors such as expected benefits and economy of scale were positively related to adoption.

A more *sociological approach* has emphasised the influence of the institutional context in the adoption process. The first study that supported this approach was Rogers' IDT[36], which described the role of communication channels, change agents and the nature of the social systems in which potential adopters had fallen as the determinants. Adoption is not a dichotomous choice, it involves a multi-step process, as theorised by some sociologists since the 1950s[48] which runs from the individual learning about the existence of the innovation ("awareness"), passing through the phase of developing interest ("interest"), mentally applying it to the specific farm context ("evaluation"), trying it on a smaller scale ("trial") to adoption. In aquaculture, one of the most used approaches to study the adoption path is the IDT; in agriculture many other models and theories are widespread such as the Theory of Planned Behavior (TPB), the Theory of Reasoned Action (TRA), the Unified Theory of Acceptance and Use of Technology (UTAUT) and Technology Acceptance Model (TAM)[16].

Finally, the *marketing approach* is described as the multiple factors that form the perspective of the supplier leading the consumer to purchase the TIs. Dissemination is based on learning about the existence and benefits of innovation, hence, information channels and the characteristics of the product itself are underlined as influential in this approach. It focuses on determinants that can predict market success and, those leading to the "*take off*", the point at which the S-curve of the diffusion denotes the moment of best success of the product[60].

In all of these approaches, there is a sensible search for the determinants of adoption. However, even though studies have exhibited great efforts to represent adoption as a long and complex process rather than a discrete event, these approaches often result in looking for the factors that influence the choice of product purchase. Hence, the projections of studies on the number of adopters often needs additional interpretations. Identifying those who have bought the technology does not mean having envied those who are truly convinced of adopting innovation and maybe have implemented or who interrupts use by trespassing in cases of partial adoption.

Phase 4 - IMPLEMENTATION

The fourth stage is "*Implementation*", conceptualised in this study as a post-adoption phase. Uncertainty associated with TI implementation has been reported by Eastwood et al.[61] who describe how it arises primarily from doubts surrounding outcomes. Several studies have investigated the implementation of innovation at the company level in the agricultural field by measuring the intensity of adoption over time in terms of the number of TIs adopted[62,63,64,65], however, few studies have attempted to focus on the propensity to innovate by the already adopting farmer. Loganandhan et al.[47]

reported that “*once adopted, there is every chance that the particular technology is being continued with the same specifications or with some technological gaps or discontinued completely*”.

In the aquaculture field, Obiero et al.[14] followed this vision by describing high adopters as those who “*had fully adopted*” TI’s components. To discern different levels of uptake, Ulhaq et al.[26] framed the initial stages of adoption, referring to that period in which fish farmers have not yet experimented or seen pilot experiences with Information and Communication Technology (ICT) and have not been able to appreciate the effectiveness of innovation. In addition, a study by Kumar et al.[66] attempted to identify factors influencing early adoption decisions, recognising the existence of different stages of use according to Rogers’ IDT[57].

Going beyond the purchase of TIs might be relevant to understand whether farmers will continue to innovate, pause at initial adoption, or even return to traditional practices. It is through the implementation phase that early adopters could be distinguished from adopters with a greater intensity to use new TIs.

Phase 5 EFFECTIVENESS

In this study, the "*Product*" was analysed as a phase of evaluating the effectiveness of the adoption in terms of expected benefits at a firm level. For this reason, it is called "*Effectiveness*".

As “*empirical studies of the welfare impact of an aquaculture-specific technology on households are scanty, but there are potential direct and indirect benefits of improved aquaculture technologies on households*”[30 (p.1)], we intend to explore the positive externalities that can result in innovation in terms of social, environmental and economic benefits.

At the company level, the introduction of TIs permits monitoring processes and improving sustainability performance[26]. In particular, PA tools offer the possibility of performing “precision”, such as the continuous and autonomous monitoring of fish biomass. This not only provides decision support to the farmer but also reduces manual labour fatigue and improves safety in the workplace. Combining manual operations with precision tools allows the combination of economic performance and social and environmental sustainability. Indeed, the feeding processes, behaviour and welfare of animals, and control of environmental and water parameters could be performed. The continuous monitoring makes it possible to improve the use of inputs, reducing production costs and operation time to gain high productivity[54,67,68]. This could lead to environmental benefits and to an improvement in water quality and animal welfare[69].

ICT systems are not applied only at the production level, but innovation engineering can be extended to the entire value chain, for example, for traceability and monitoring the quality of the final fish product[26]. In addition, they can result in indirect benefits to all fish value chain actors as their introduction can reduce fish prices and incentivise the creation of jobs and higher wages even outside the industry[30]. Their dissemination might also increase competitivity within the aquaculture sector through an increase in supply for the internal market[70,71].

In addition to the positive aspects, it is important to ensure that the technology does not pose a negative impact on future farming reality. In this sense, innovation is given a responsible role in ensuring not only economic, but also socio-ethical benefits. The field of responsible research innovation (RRI) is enhancing evaluation tools that can measure innovation's "effectiveness". This strand emphasises the importance of analysing the possible impacts of innovation on individual beneficiaries, society and the ecological environment in order to modify innovation objectives and strategies in the face of changing scenarios[72,73].

2.1 Contextualising the AKAIE in the aquaculture sector

The AKAIE model could offer a key understanding of the adoption process at each stage, thus, the next step is to interpret the sequence in the light of the context in which the innovation processes occurred. The stages of this sequence should be contextualised on the basis of two aspects (Fig.3):

i) The company level, represented by intrinsic structural factors which in this paper are defined as "on-farm";

ii) The institutional level, represented by extrinsic factors of the context which are defined as "off-farm".

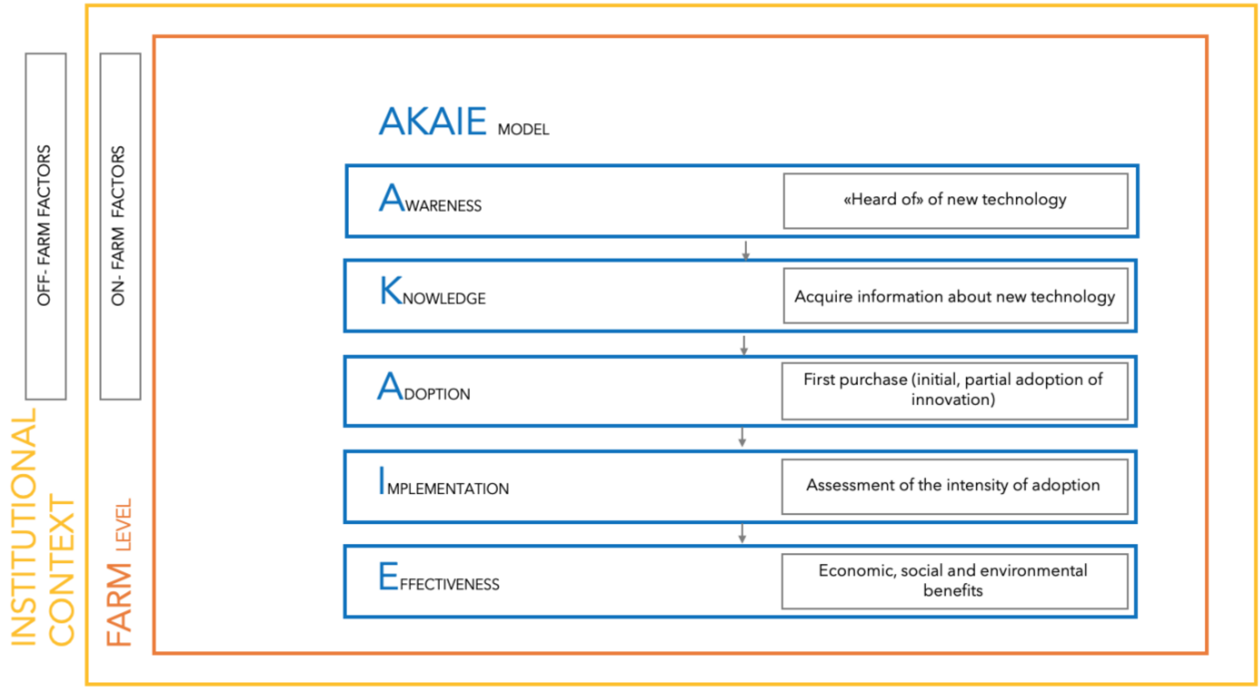

Fig.3 On-farm and off-farm factors as key elements to interpret the Awareness Knowledge Adoption Implementation Effectiveness (AKAIE) model (own elaboration).

On-farm factors

Aquaculture studies are controversial in terms of the correlation between age and adoption, both positive[20] and negative [25]. Wetengere[18] provided insight on this by proposing a study where the influence of many variables on the intensification of technology in aquaculture was evaluated on three levels, from the least to most intensive use. According to the majority of adoption studies on agriculture[74] results of Wetengere[18] indicated that younger individuals had a greater propensity to innovate; however, they registered the lowest level of adoption. Whereas the elderly were positively correlated with a greater intensity level. Although these results need to be interpreted in the context of innovation, these findings have occurred because adults tend to carry on a family business, while younger people are more likely to take other opportunities[18]. For the same reasons, Wetengere[18] reported that women were more motivated to intensify fish farming activity. Furthermore, producers with a higher level of education, who undergo continuous training[14,23] and in general were well informed [18,24] tended to be classified as more inclined to adopt. It is important to highlight that a farmer's knowledge of TIs depends on their level of education and personal experiences and also on the influence of information sources (e.g., family and friends; their involvement in clusters; the role of farm advisors)[14,29].

Some studies highlight how uptake was also well combined with diversified[14] and large farms with greater financial possibilities [23,66] and higher household income levels [25,26]. Other studies indicated that small-scale farmers were more willing to adopt these technologies when fish farming was their dominant activity; the converse result occurred for larger farms[17,24]. Small-scale producers often interface with very low local demand, which does not encourage them to implement the business or invest, unlike those who can take advantage of demand from nearby cities or wholesalers[75]. Furthermore, large farms could have a stronger beneficial influence on other farmers to adopt these new practices[26]. Caffey and Kazmierczak[76] determined that an external income could represent a method to tolerate the initial costs of purchasing technology in grab production. The initial cost of investment has a high perceived risk associated with these technologies and is described in existing literature as a major reason for non-adoption[66].

Off-farm factors

The institutional context in which innovation operates is often referred to as the ecological environment, policy, markets and socio-cultural dynamics[10,22,23,77]. Studies by Loeber[78]and Elzen et al.[79] explored the concept of "*anchoring innovation to a context*" to assess potential scaling by defining the micro-, meso- and macro-levels. This multilevel perspective helps to define the dynamics that occur within innovation processes moving from the level of technological niche, passing through networks, to the systemic dimension defined by the institutional context in which they are dropped[80]. Studies addressing the contextual dynamics conducive to innovation adoption in aquaculture are scarce, and most still propose to explore fish farming adoption[28,81]. The reason why they still analyse the factors leading to start-up aquaculture activities is because most studies have been conducted in developing countries where issues of access and availability of material and financial resources are primary. The certainty of receiving material (equipment, training, etc.) and financial support from public and non-governmental institutions, as well as efficient local administrative structures are driving forces for adoption. Further, the difficulty to source feed or fries and the impossibility of having fast transport to deliver the production in controlled conditions prevents them from leaving the market logic marked by local demand and therefore from exploring more innovative trajectories[75]. Thus, fish seed networks are growing, especially in Asia, boosting aquaculture activities in inland areas[82]. The adoption of innovative selective breeding can provide great results, although it is not highly widespread due to economic and training difficulties and low level of public support[83].

Socio-cultural factors, such as religion and ethnicity also direct, for example, the consumption of fish on certain days. Cluster membership itself enhances social relationships and drives shared cultural habits but also uncertainties and responsibilities[29,75]. In particular, Joffre et al.[29] demonstrates how group membership is positively correlated with a higher likelihood of adoption. Indeed, the power of collective action leads to knowledge sharing, which goes beyond the farmer to farmer knowledge emphasised in many studies[e.g.,13,84]. Similarly, the frequency of interactions and the relationships of trust that are established, especially with relevant actors in the aquaculture sector, strongly influences decision-making processes[29]. The clustering of multiple segments of the value chain in a local area has been demonstrated to boost innovation adoption among aquaculture farmers[85].

Information sources exert different influences based on user type and when they intervene in the adoption process[20]. Brugere et al.[22] demonstrated that in the adoption of aquafeed containing non-conventional ingredients different types of feed users were affected by different social pressures: farmers using commercial feeds were increasingly influenced by the approval of neighbours and family, while those using farm feeds were perceived the opinion of other farmers or feed suppliers as more relevant. In addition, extension and advisory services, offered by graduate students, ministry experts or territorial extension agents, play an important role in promoting new practices in aquaculture[3,27,75]. For example, extension support and involvement in research programs were found to be positively associated with alternative catfish production technologies adoption in the early stages[66].

2.2 Which is the role of aquaculture farmers' perception in the adoption process?

To correctly interpret the adoption sequence, it is necessary to analyze the context in which the innovation is dropped, as was discussed in the preceding section. For these reasons, the influence of structural and institutional components on the decision-making process have been discerned. In this scenario, there is a need to deepen the behavioural component[49], thus understanding which role is involved in the perception of this theoretical framework. Perception plays a relevant role in the decision-making process leading to the adoption of innovation and it has been explored in different ways[18,22,35,86,87,88].

A much broader strand encompasses studies[20,88] sustaining most conventional approaches by proposing perception as highly driven by the characteristics of innovation, according to Rogers' IDT. Specifically, some studies have demonstrated that the perception of increased yield[66,89] and ease of understanding were positively associated with a higher likelihood of uptake of innovation in aquaculture[14]. In contrast, others highlighted how aspects of compatibility with current practices and trialability of innovative practice were more critical than economic aspects[22].

In addition to Rogers' framework, many studies[18,19,22,66] include perceived production and financial risk as attributes, the minimization of which is positively associated with adoption. In general, the perception of risk as an element is emphasised as being influential in the aquatic environment[90]. Wetengere[18] noted a good chance of intensifying uptake if the new tools proved to be profitable and if fish products were easier to raise and more marketable and desirable.

Perception has also been proposed to be shaped by normative, control, and behavioural beliefs, according to Ajzen's Theory of Planned Behaviour[91]. Brugere et al.[22] emphasised the importance of behavioural beliefs such as "*the perceived importance and effectiveness of innovation*"; normative beliefs such as "*social pressure and approval from other actors*" in the fish supply chain; and control beliefs such as "*perceived barriers or incentives*". Among them, perceived peer pressure and outcome uncertainty were determined as the most significant. Social norms exert a relevant influence on this decision because farmers exhibit a greater intention to adopt if they witness their peers' trialling innovation and demonstrating expected outcomes[26].

Fewer studies (e.g., Diedrich et al.[28]) have been influenced by psychological[92] and behavioural economic[35,93] fields, in which perception was clearly analysed as key to understanding the external context and thus as a central node of the adoption process. The same psychological studies emphasised how behaviour was the result of interconnections between individuals and the environment. The individuals developed a positive or negative attitude towards adoption as it expresses the environment subjectively perceived[94]. Obiero et al.[14] and Ndah et al.[75] described how perception was directly related to adoption propensity in aquaculture highlighting both the contribution of the first strand mentioned above and sociological approaches, conceptualising perception as driven by on-farm and off-farm characteristics. In the agricultural field, Vecchio et al.[35,41] managed to incorporate the influences of the context by proposing to investigate the process of innovation adoption through the indicator "*perception of complexity*", in which the most relevant technical-economic, financial and organisational aspects were encapsulated. In these studies, the perception of complexity, defined as a subjective mental process shaped by the structural profile of the farm and by the environment in which innovation occurs, decreased from non-adopter to adopter. The present study follows the latter conceptualisation (Fig.4) where our model proposed to consider perception as a central node of the adoption process.

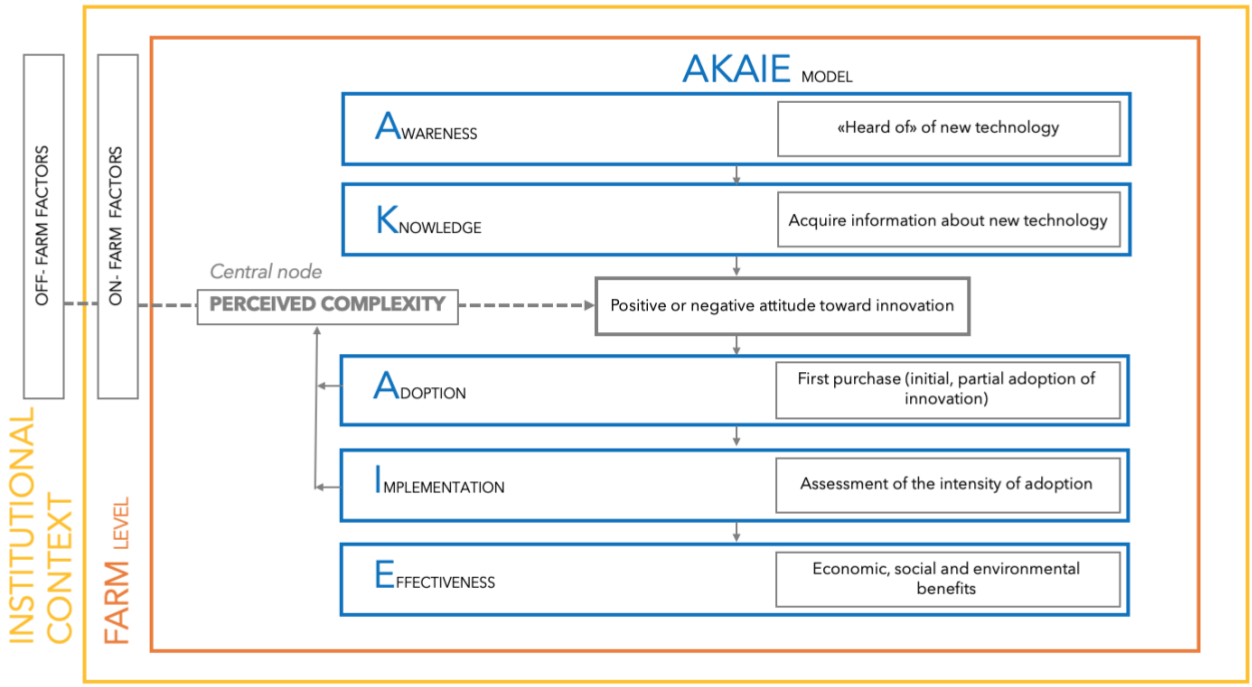

Fig.4 Perception as the cornerstone of the adoption process in aquaculture (own elaboration).

3. Discussion and Conclusions

Aquaculture boasts greater diversity in terms of feed, production processes, disease, products and farm buildings. Several TIs have considerably contributed to sustainable development of aquaculture, and these have been made possible by scientific and technological advancements. However, still many barriers are reported in the literature that according to Yue and Shen[95] mark a slow pace of adoption of innovation compared to the current development of aquaculture. A more in-depth study of the adoption process and its contextualisation could also be very useful to analyse the reasons why certain TIs register greater acceptance in different contexts and for different productions within the sector.

This study aimed to assess the process of TIs uptake in aquaculture, both in the pre- and post-adoption phases by proposing the theoretical sequence of AKAIE.

The model attempts to identify a number of dimensions from awareness to effectiveness as perceived complexity, institutional and farm contexts may have different weights in the technology adoption process, depending on the nature of the technology itself[96]. This model, however, allows for scalability of the adoption process because it is possible to change the indicators within different stages, allowing for possible standardisation when comparing the adoption processes of different technologies. The model has a limitation which was due to the assumptions as it is not possible to compare the results of the process for different technological innovations.

To conduct this theoretical analysis, a literature review was performed on the available studies. Unlike the agricultural field, this topic requires further exploration. Most existing studies tended to analyse the drivers and barriers with respect to the initial adoption of technology, which coincides with the first use/purchase of the innovation. A model that could provide a key understanding of the TIs adoption process for the aquaculture sector has been proposed. From the model, three main concepts emerged:

i) Adoption of innovation is a multistage process and perception plays a key role;

ii) Perception should be considered as a central node of the adoption process and should be studied by including the influence of on-farm and off-farm variables;

iii) The AKAIE model could represent a tool for assessing the post-adoption phases, including "*Implementation*" and "*Effectiveness*" of innovation in aquaculture farms.

The proposed sequence allows the identification of bottlenecks in the pre-adoption, purchase and post-adoption phases. The pre-adoption phase begins from the moment the individual learns about a technology for the first time and continues with the phase of developing interest and knowledge. At this point, based on the knowledge gathered and the context in which the technology acts, the individual forms a more or less complex perception of adoption. This indicator should be assessed differently for a non-adopter and an early adopter and a user who desires to implement TIs. The non-adopter should exhibit a greater perception of complexity compared to an individual willing to innovate or an adopter. In the same way, an individual who has already adopted and intends to implement has an even lower perception than an adopter who has just purchased the technology. The initial stages of adoption mainly concern the purchase of the technology, and to reach a more advanced level of adoption the individual needs to acquire technical aspects regarding innovation ("*How-to-knowledge")* and also principles and benefits it can ensue ("*Principles-knowledge").* In general, the post-adoption phase includes the possible implementation of TIs and the concrete evaluation of the benefits received. Reaching the stage where the benefits are visible not only demonstrates the "*Effectiveness*" of adoption, but also that the individual has fully understood the innovation and reasons for uptake. A good effectiveness result can demonstrate the effectiveness of political action in supporting innovation. Indeed, this model could represent a tool for understanding the effectiveness of innovation in a given context and therefore an additional tool for policy makers to understand the state of the art of innovation's uptake in a specific context and to formulate new measures of intervention for the diffusion of TIs in aquaculture.

Researchers and institutions at a global and European level are striving to support change towards more competitive and sustainable aquaculture models that include the adoption of innovations. Past experiences have demonstrated how the possible technological developments within a key sector, such as aquaculture, can become a driver to achieve the UN 2030 goals, as well as contributing to the realisation of several SDGs and regional strategies such as the European Green Deal. For this reason, measures bridged by regional policies, such as the EMFAF in Europe, focus on the dissemination of technological innovations in the aquaculture sector. However, the need for monitoring tools to assess the effect of the policy measures implemented is increasingly important. Ex-post evaluations of the effects of policy measures are common in existing scientific literature[97], however, our study forms part of the possibility to offer a new model to evaluate the current state of the dissemination process of a given technology, offering the policy maker the possibility to be able to act promptly in order to improve the effectiveness of the measure deployed. As a result, following the strand of RRI could highlight the vision of making innovation policies responsible. The development of tools for evaluating the effectiveness of innovation is more necessary than ever, especially to orient strategies and interventions in the face of major scenarios of change. In recent years, challenges have become increasingly complex, from the climate crisis to the COVID-19 pandemic and the recent Russia-Ukraine war. Major crises often represent moments of great change, opening a window on unforeseen and sometimes unprecedented scenarios that alter perspectives to consider the future of society. These times often result in the strongest reflection of mechanisms for developing innovations in response to crises, following Mill's theory[98]

Future research foresees the application of the AKAIE model to empirical cases to evaluate the propensity to innovate some aquaculture producers and to investigate how this model is perceived by aquaculture policy networks. Further studies should focus on understanding the influence of the on-farm and off-farm factors explored in this paper at different stages of the adoption process in aquaculture.

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Fourth Chapter

Title page

Responsible policy for innovation in aquaculture

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1. Introduction

From the first Green Paper in the mid-1980s to the present day, the story of the Common Agricultural Policy's (CAP) reform path has been shaped by the intersection of agricultural and environmental policy. The gradualness and how this integration, which is still in progress, has led to the identification of the European policy approach to the agricultural sector as the result of a dynamic mix (Alons, 2020). It was tweaked reform by reform between two competing philosophies: the productivist one that helped shape the Common Agricultural Policy (CAP) and is "constitutionalized" in the Treaty of Rome, and the liberalist one that reaped the benefits of the strong impetus that followed the end of the Cold War and the negotiations on international trade and led to the formation of the World Trade Organization but fizzled out at the turn of the millennium (WTO). The "multifunctional" paradigm was born from the collision (and sometimes contradiction) of various philosophies. As the belief in the permanence of the phenomenon of market globalization gained traction, fueled by the shift in the level of confrontation between nations from war to the commercial level, in which the use of sanctions appeared capable of quelling the expansionist ambitions of other countries, this approach was able to hold together a variety of goals, including food security (Ikemberry, 1999). Reading the legislative documentation that accompanied the drafting of the CAP reform for the period 2021-2027 today, the functions and objectives that are most emphatically highlighted are the fight against climate change, or the climate crisis, the improvement of animal welfare, environmental protection, the enhancement of the landscape, the sustainable development of rural areas, and the competitiveness of agri-food systems. Through a significant shift in the structure of direct payments, this reform seeks to improve the agriculture sector's social and environmental performance in Europe.

Agriculture paved the way for fisheries and aquaculture to become greener (Napier et al., 2020). Indeed, fisheries policy has developed in a similar way over time. The inclusion of fish products in the Treaty of Rome, as well as the first regulation established in 1970, which established a policy to encourage the modernization of boats and coastal infrastructure are examples of the productivity paradigm. Given the goal of establishing a free trade area under common rules so that a fisherman from any member state could access all common waters, these regulations likewise exhibit a liberalist perspective. Problems with over-investment in the fleet and overfishing were recognized even as early as the 1980s, leading to stricter laws and controls and the need to create a sustainable blue economy. Since the reform in 2013, aquaculture activities have also been required to take environmental responsibility for maintaining long-term sustainability and to be managed in a way that is consistent with the objectives relating to the economic, social, and employment advantages to be obtained. To improve protection of aquatic biological resources and ensure food security across the EU, Italy is working on its National Operational Programme 2021-2027 for the European Maritime, Fisheries, and Aquaculture Fund (EMFAF).

The Communication on “From farm to fork " which is a part of the larger European Green Deal initiative, sets ambitious targets for the contribution of European agriculture to combating the climate crisis and provides impetus for a more rapid transition toward sustainability and, more broadly, a circular economy. A logic of compensation for the production of public goods and services, with a particular and considerable interest in livestock and aquaculture systems, is guiding the ecological transition of agri-food. To lessen their negative effects on the environment and to accommodate the rising standards of European culture for animal welfare and, more generally, the idea of "One health," livestock and aquaculture farms are called to reevaluate their current technical and organizational methods (Erklavec et al., 2021). Consequently, the renewed European political instrumentation, also in its national forms, is called upon to accompany this process, acting as a channel for the demands of the community, which in turn reshapes the relationship between production systems on the one hand and the environment, society, and markets on the other. In particular, concerns have been raised about the possibility of a widening gap between European and supplier standards, which would encourage a re-localization and concentration of negative externalities outside Europe (Fuchs et al., 2021). The Green Deal is the impetus behind the new chapter of Fisheries and Aquaculture Policy (FAP), which will be recognized in the EMFAF's programming and CAP beginning on 1 January 2023.

Agricultural, fisheries and aquaculture products are initially regulated by the same CAP and after years of distinct policies, sanctioned by the creation of the EMFAF, they are now being called to order by European challenges to achieve common goals. If European challenges are the lowest common denominator for both policies, they also seem to suggest to terrestrial and aquatic farming the need for common instruments.

Among these, promoting the diffusion of technologies and organizational structures capable of achieving maximum trade efficiency with the environment at the level of individual production systems and in integration with the market is the primary foundation for Europe's aspiration to be the first climate-neutral continent.

With this strategy, consideration must be given to the full hierarchy of energy flows that occur between production and consumption and between these activities and the available stocks of natural resources. Micro, meso, and macro levels of study can be distinguished in the context of a production systems as different levels in which innovation could act (De Rosa et al., 2021).

At the micro level, there is the functional unit, which may be either a plant or an animal; at this level, the effectiveness of the functional unit's metabolic activities should be taken into consideration. Production systems are considered to be the intermediate meso level. At this level, the dynamics of energy exchanges are governed, on the one hand, by the technical and organizational characteristics of production and, on the other hand, by the particular environmental and agro-ecological conditions of the context of reference. In other words, production systems are a combination of these two factors.

The third and greatest level determines whether or not the value of a product or service is acceptable for widespread consumption by the market, society and policies .

Only by fostering effective innovation action for a neutral balance between use and regeneration of natural resources can policies make a decisive contribution at all three levels. In the face of the opportunities that technology can offer, however, it is also important to promote Responsible Innovation Policies (RIP), capable of foreseeing negative scenarios and ensuring that production systems and stakeholders actually receive or benefit from the benefits that technologies can offer. While this aspect has been more studied for land-based production systems within the research field of Responsible Research Innovation (RRI) (Rose and Chilvers, 2018; Bronson, 2019; Vecchio et al., 2022), limited attention has been given to the fisheries and aquaculture sector in promoting responsible policies for innovation. The need addressed by this study is precisely to analyse a possible framework of responsible policies to ensure that aquaculture, as a sector that will play an increasingly key role in guaranteeing food and nutrition security in the world, can, with the support of new technologies, follow paths of sustainability and circularity.

The objective of this paper is to study policy action in the transfer of innovations in the aquaculture sector, focusing on the responsibility that policy action should have to ensure equitable benefits within the sector. The evaluation of the effectiveness of policy action will be analyzed by applying the principles of RRI in a systematic way at the three levels highlighted.

2. Theoretical background

Supporting the diffusion of innovation in agrifood is getting increasingly challenging. The new 5th SCAR report ("Resilience and transformation") identifies three goals for innovation (EC, 2020): a) ensuring that everyone has access to nutritious, healthful, and sustainable food; b) ensuring that food and agricultural systems are fully circular; and c) restoring diversity in our food, farm, and social systems. Adapting production methods to new circumstances is a time-consuming but necessary part of embracing innovation. When an innovation enters the food system, it affects every part of the food supply chain. These may prompt adaptive changes that have either a beneficial or negative effect, or even no effect at all (National Research Council, 2015).

The intricate character of both the innovation process and the production system into which it is introduced explain this phenomenon. Academics use a definition of complex adaptive systems to define agri-food systems (National Research Council, 2015), their complexity stems from their structure and the dynamics of their non-linear parts. They are distinguished by the presence of a wide variety of actors—from farmers to the largest aggregations in the institutional contest—each of whom reacts in a unique way to the environment. These agents make choices independently and adjust to new circumstances while also taking into account the needs of those around them. Different configurations of the system are the outcome of their interaction, and these configurations determine the system's behavior (Miller and Page, 2007; Hammond and Dubè, 2012). As may be predicted, today's agri-food systems are extremely varied and characterized by intricate processes and socio-institutional dynamics (Edwards, 1980; Fratamico et al., 2005). When describing the intricacy of today's agri-food systems, Klerkx (2020) use three terms. The first is “transformation”, which is now required for the agri-food system to become more resilient, sustainable and circular. The second is "disruption" as new technologies are needed to embrace this transformation. The third is “plurality” and it is about depicting the multiple transition pathways of the agrifood systems.

Facing this complex framework, new pressures have been put on agri-food systems, and the innovation processes that sustain them, to yield the desired outcome for the agriculture of the future, particularly in environmental and socio-ethical perspectives (Rijswijk et al., 2021). In fact, the effects of innovation have broadened their boundaries to include non-economic issues, and there is a growing body of research, called RRI, that encourages the responsible adoption of innovation pathways (Stilgoe et al., 2020).

Few studies have looked at how widely RRI's principles have been implemented in precision farming (Bronson, 2019; Eastwood et al., 2019). Responsible innovation (RI) in agriculture calls for research into four areas: reflexivity, anticipation, inclusion, and responsiveness (Charatsari et al., 2022).

“Reflexivity” has been defined as the promotion of new reflection processes around innovation processes by including all prospective actors to reduce negative impacts while enhancing positive outcomes, and “anticipation” is related to the capacity of research and innovation policy to anticipate an unfavorable scenario in terms of potential environmental and socio-ethical risks. Then, actions for increasing people's “inclusion” and confidence in the innovation process include soliciting feedback from a wide range of interested parties and adopting a bottom-up approach to governance. The final principle of “responsiveness” includes the ability to facilitate a change of direction within innovation processes facing new knowledge and information dynamics, as well as new challenges.

Numerous innovations with significant potential but considerable uncertainty have propelled the RRI literature to the forefront. However, there is a dearth of implementations in PF technologies (Bronson, 2019). Many authors have described for the fisheries and aquaculture field various obstacles to adoption, such as high costs and high levels of difficulty in using the technology (Joffre et al., 2020). Since researchers have pointed out the obvious difficulty in the transfer and adoption of TI, it may be very helpful to analyze the desirability of PF through the RRI lens.

To analyse the effects of innovation in complex agri-food systems, it is necessary to analyse the three levels of production systems by extending the principles proposed by RRI.

Micro level

At the micro level, there is the functional unit, which can be, for example, the plant or the animal, whose metabolic efficiency must be considered. Innovation at this level is to support technologies that can improve farm management techniques (i.e. feeding, hygiene and disease control, welfare) or to support genetic improvement techniques that can make animals better performing, less impactful and more resistant (Kumar and Engle, 2016). At this level, support for new breeding programmes, increased access to precision farming tools (such as precision feeding, monitoring systems, diagnostic tools) or access to specialised animal welfare measures and advisory services are examples of the micro-level effects of the strategy of a responsible innovation policy for aquaculture. In particular, this would meet the principle of responsiveness. For example, knowing the metabolic performance of a fish, it would on the one hand make it possible to make processes transparent and from the use of technologies on production, and on the other to redirect innovation processes once new knowledge about the raw materials is gained.

Meso level

Production systems represent the intermediate meso level, wherein the dynamics of energy exchanges are governed, on the one hand, by the technical and organizational characteristics of production and, on the other hand, by the specific environmental and agro-ecological conditions of the context of reference.

Among innovation technologies at this level there are sustainable farming systems, i.e. recirculation aquaculture systems, biofloc technologies, and integrated systems (Bush et al., 2021).

Investment in more sustainable farming systems or individual and supply chain measures, cooperation in research and innovation, and support for extensive approaches are all examples of intermediate-level impacts resulting from the strategy of RPI in aquaculture. More in detail, adopting more innovative systems would allow potential trade-offs, synergies, efficiencies to be anticipated (anticipation), even if undesirable effects are still difficult to be predicted. In addition, it could lead to rethinking the company's needs in response to new challenges (perhaps to be sought in new collaborations with public or private entities), while respecting the principles of reflexivity and inclusion. In the face of changed conditions, the possibility of acquiring knowledge through innovative monitoring mechanisms of business processes can help steer the company towards the desired transformation (Responsiveness).

Macro level

The third and highest level governs the widespread approval of products and services with sustainable and circular qualities. It determines whether or not the value of a product or service is acceptable for widespread consumption by the market, society and policies. Aquaculture can benefit from multi-actor technologies such as innovation platforms and company incubators (Bostock et al., 2016). More systemic approaches to innovation are increasingly required to better climb different levels of complexity (technological, socio-cultural, institutional, and environmental aspects of the sector) and to stimulate innovation for sustainable aquaculture by promoting learning processes among actors and improving the ability to anticipate changes for the sector (anticipation). This is because more systemic approaches to innovation are required to better climb different levels of complexity (technological, socio-cultural, institutional, and environmental aspects of the sector).

In this sense, access to more transparent agri-food processes, in terms of credible evidence and metrics, could provide policy makers with the right backdrop against which to rethink more responsible and contextually calibrated innovation policy instruments. This will also make it possible to re-enter innovation policies in a systemic sense applied at different scales, including all actors and activities impacted (inclusion), as well as to provide information on innovation objectives, main expected outcomes and publicly available budgets.

4. Conclusion

Using this foundation, this work raises questions about how well we can discriminate between two nodal features of this complicated picture.

One of the first considerations is how farm advisory services might be repositioned to be more useful in the current environment. Thus, it is important to study how innovations are shared across territories and to promote processes that work from the ground up. As a result, AKIS systems will be heavily weighted in the future planning of agricultural policy, as they may play a significant role in the modernization of the sector via the expansion of knowledge, innovation, and digitalization in agriculture and rural areas, primarily via the CAP strategic plans of the Member States. To acquire new knowledge and foster an atmosphere conducive to innovative solutions, the policy network, agri-food chain actors, research, associations, and consultants will need to work together. This circumstance will help promote an open innovation path, which will aid in accelerating current innovation processes, making room for new ideas, and contributing to the goals of the new CAP. This fresh perspective has the potential to aid in the digital transformation of small farmers and provide them with equal access to digital opportunities (Vecchio et al., 2021). According to the classification described by Laurent Klerkx, the issue of knowledge and innovation has become essential to European policy planning in an environment characterized by drastic transformations that characterize modern agri-food systems (2020). The meaning and character of inventions have shifted significantly in this setting. Two primary causes account for the shifts. The first is an emphasis on conducting needs assessments across industries and geographic regions to identify areas where innovations might be implemented to meet real demands. The second has to do with including more people from various backgrounds into the creative process. The process of co-creating innovation involves participants from many different sectors, not just those in research and production but also those in consulting, education, and the public sphere. The Standing Committee on Agricultural Research (SCAR) prompted this slow but steady progress by pointing out in the early 2000s the distortions of linear models of knowledge transfer, highlighting a substantial inability to provide answers to the main structural and systemic changes due to knowledge and innovation models anchored to old paradigms (productivism) and linked to "path-dependence" type schems. Community agriculture policies have recognized the systematic approach to knowledge and innovation as a vital aspect in the face of new difficulties posed by this situation. However, adaption processes have been slow, and dangers of path-dependency have frequently caused distortions that have prevented the many farming methods and diverse agricultures from receiving enough support.

The second aspect we want to stress is how little research has been done on the potential benefits of applying RRI-related ideas to the relatively new field of precision farming. RRI proposes to entrust research and innovation with new obligations in assuring beneficial outcomes for tomorrow's agri-food in light of the new responsibilities entrusted to agriculture today, which must be more inclusive and innovative, but also more sustainable, greener, and circular. Lack of defined frameworks on how to secure things like "inclusivity" or "ethical digitalization" makes policy action ineffective (Lioutas et al., 2021, Vecchio et al. 2022). Immediate reinforcement of this framework is necessary to promote the transfer of innovation in a socially and environmentally responsible way and to forestall the potential negative outcomes of digitalization both inside and outside of businesses (e.g. concentration of power in major Ag-Techs, gap between large and small firms and countries, and destruction of biodiversity). There are many technological innovation tools to achieve improvements in different areas such as genetic improvement, nutrition, mechanization, hydro-geological planning, management of natural resources, and animal care and welfare, research is essential.

In addition, innovation platforms or innovation hubs involving more and more industry players are growing to improve management practices, marketing requirements, certification schemes, traceability and other practices through cross-fertilisation of expertise.

These advances typically exceed the financial, structural, and cultural capabilities of a single farm, necessitating mostly group management solutions (van der Ploeg, 2006). The ramifications of this find new ground for study in the political and economic spheres. In the pursuit of a competitive and sustainable aquaculture industry, the selection of the best institutional solution for the diffusion of innovations becomes a priority. Skills, capacities, and knowledge that are regarded essential for managing innovations are also defined in this approach (Huffman, 2001).

It is also important to define where innovation fits into the micro, meso, and macro levels of innovation. This study could give insights by promoting a process of reflection on what might be the most effective innovations for the different levels of analysis. The innovation process that is to be supported from the micro to the macro level should be able to ensure the responsibility of technology in guaranteeing the expected economic, environmental and social benefits. This holistic vision could also be at the service of future policies in accompanying production sectors towards a gradual and guided transition.

Monitoring production processes through technological innovation would also help lay the groundwork for predicting the future effects of technology, anticipating the need to review existing practices and promoting more responsible policies, targeted also to changing social needs.

Future research should focus on identifying indicators that can measure for each technology a relative advantage over more traditional practices, based on the four principles of RRI.

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Discussion and Conclusion

In the scientific economic literature, innovation is a topic to which much attention has been devoted since it represents a key driver for economic growth. It was Schumpeter who first questioned the difference between 'invention' and 'innovation' in 1911, pointing out that the former does not necessarily entail the introduction of a new product or process onto the market (Schumpeter 1912). The entrepreneur assumes a double link with innovation, in fact in 1994 Allen will define Schumpeter's entrepreneur as an innovator. Schumpeter defines innovation as creative destruction (1942), stating that it is a process of industrial mutation, incessantly revolutionising the economic structure from within, incessantly destroying the old, incessantly creating a new one. This happens within a sequence of four stages: invention, innovation, diffusion and imitation. At a later stage, Schumpeter himself, would revise his position on the innovation process, shifting the view from an individualistic process (the entrepreneur-innovator) to a collective process, to the extent of extending the role of innovator to the state as well (Sledzik, 2013).

In order to best analyse innovation, it is necessary to start from the analysis of organisational models. Indeed, there is a correlation between technology, business organisation and social institutions. In the steps of technological progress, one can recognise routine phases that Dosi, in 1988 identifies as: (a) innovation causes uncertainty (not only determined by information asymmetry); (b) uncertainty is opposed to the willingness to experiment with novelty; (c) increasing complexity reduces the success of the individual innovator, the Schumpeterian entrepreneur, while it favours group innovations; d) evolution does not make the innovative component from learning by using/doing disappear (Rosemberg and Nathan, 1982), although the strong propensity for computerisation and more recent digitalisation is weakening this factor; f) change is conditioned by the current state of innovation. Neoclassical theory, on the other hand, focused on the market-innovation-firm link. It assigned the firm the simple role of processor (hence a simple decision maker of something already given). At that stage, innovation is seen as a gap between two moments, t and t+1, and not as an evolving process, so it does not focus on what happened to the black box between the two reference periods. So, the behaviour of firms in this theory can be summarised in two types: in the first case the firm behaves as a technology follower, waiting for innovation to emerge and moving from the old to the new technology; in the second case the firm has the choice to adopt or not to adopt (but implicitly the choice not to adopt excludes you from the market). Still in the neoclassical vein, Manfield (1968) characterises the diffusion of innovations model as an epidemic model, depicting it as an S-shaped function (logistic curve). In an attempt to overcome the problems of this approach, the time variable must be taken into account, so as to switch to a dynamic view, advocated by Austrian economists.

At the same time, the pioneering work of Rogers in 1962 developed, the so-called "diffusion model", which aims to explain the diffusion process of innovations within agricultural communities. Adoption is defined as a decision to fully utilise an innovation as the best available course of action while the process in which an innovation is communicated through certain channels over time among members of a social system is known as diffusion (Rogers, 2003). Feder et al, (1985) defined adoption as a mental process that an individual goes through from the first time he or she learns about an innovation to its final use. Fisher, Norvell et al, (2000) explain that diffusion differs from adoption in that it is the process through which new technologies are disseminated among users whereas adoption is considered an internal individual decision. Criticisms leveled at the model are the categorisation of adopters, the contextual lack of consideration for situational variables, the determination of the adoption process as a sequential and not a holistic process and the determination of the characteristics of innovations (Rogers and Shoemaker, 1971, Tully, 1968). All these critical issues lead scientific research to develop new models, such as relational models, which attempt to bridge previous gaps by focusing on assessing the needs of adopters. These models seem to improve the analysis of the innovation transfer process, as they involve all actors, without a top-down approach. This brings us to Evenson's work of 1997, which with the AKAP sequence succeeds in capturing both the consequentiality of moments in the adoption process and in capturing contexts. It is developed for services, which is why an extension is proposed in this work to better encompass the implementation phase that characterises the introduction of a physical product. This allowed us to detail the new model, the AKAIE, which could offer the policy maker a tool for evaluating the efficiency of policies for the dissemination of innovations.

Following the stages of the adoption process through the AKAIE sequence and the numerous factors influencing it, the work considers the role of perception as primary. The work drew a line in time and then went on to discuss the cognitive sphere of the individual. This was done through the use of a qualitative-quantitative technique, Q-methodology, which highlighted the views of both practitioners and policy makers.

Based on the route taken and on results of the present study we can ask ourselves a question for the development of future research: do we have the tools to make responsible policies for innovation? To date, based on the results obtained, the tools available are many but still difficult to implement. In particular, it is difficult to have tools that are able to avoid the negative event of immediate diffusion of the technologies themselves, such as the creation of monopolies. The current state of the art does not allow a substantial database for the creation of a reliable history on which to create “prior knowledge”, due to low diffusion or average diffusion with low implementation. As we have shown in the first paper, the analysis of bottlenecks to technology adoption is only the starting point of the potential aspects that help to support an effective path of responsible innovation, from the company perspective to actions implemented at the policy level. Future RRI efforts require further efforts by all stakeholders to fully incorporate RRI dimensions into PFs in order to create more responsible policies.

These PF technologies explored on micro, meso, macro levels now enable the path of sustainable intensification of the aquaculture sector, helping us to encourage the development of responsible innovation policies. In order to drive a propulsive motion towards the creation of effective measures, the AKAIE model offers a broad design on which different needs can be declined based on the context in which one operates and the business environment itself, without neglecting the analysis of the involvement of the entrepreneur's attitude.

The strength of the AKAIE model lies in its ability to provide indications of the effects of adoption within sectors, providing both diffusion scenarios in terms of improving the efficiency of the sector, but also anticipating possible problems, and in systemic terms, with high degrees of diffusion and low degrees of implementation, but also with the effect of understanding at which stage in the cognitive process of the actors involved diffusion has stalled, thus attempting to intervene at the level of awareness, knowledge or mediation of the individual's perceptions.

The combination of innovative technologies and a model for studying the adoption process, such as AKAIE, could be a winning mix to achieve the goal of responsible policies for innovation.

The project is not conclusive, but leaves ample room for future deepening, such as the possibility of empirically testing the model on some case studies and the possibility of structuring an econometric model to identify indicators for each stage and level of the model.

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