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An analysis of climate change impact on agri-business companies: risk management, performance, and disclosure policy.

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Sommario

Introduction

In recent decades, climate change and sustainability have become increasingly prominent on the global agenda, attracting the attention of governments, international institutions, businesses, and civil society. This growing interest reflects widespread awareness of the profound and cross-cutting impact that climatic transformations are exerting on the environment, the economy, and society worldwide. An official and widely recognized definition of "climate change" was formalized in 1992 during the United Nations Conference on Environment and Development, known as the Earth Summit, where it was established that climate change refers to any alteration of the climate directly or indirectly attributable to human activity that alters the composition of the global atmosphere, beyond natural climate variability observed over comparable periods (UNFCCC, 1992).

> *"Climate change means a change in climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere, and which is in addition to natural climate variability observed over comparable periods of time."*
>
> Earth Summit, 1992.

The increase in concentrations of greenhouse gases and other climate-altering gases has led to a rise in the frequency and intensity of extreme weather events such as heatwaves, prolonged droughts, and intense, unpredictable precipitation. These phenomena, in turn, cause both direct and indirect effects on the territory, including soil degradation, biodiversity loss, and disruption of natural ecosystems. Such events not only pose an environmental threat but also produce significant social and economic repercussions, exacerbating inequalities and destabilizing traditional production systems.

Within this complex framework, the agri-food sector stands out as one of the economic sectors most exposed to the impacts of climate change, while simultaneously representing a key factor in mitigating its negative effects and promoting sustainable development. The Intergovernmental Panel on Climate Change (IPCC, 2024) emphasizes how agriculture today faces multifaceted challenges: ensuring food security for a growing global population, preserving biodiversity and ecosystem balance, and adapting to increasingly unstable and unpredictable climatic conditions. Climate projections indicate that the most pronounced effects of climate change will be felt particularly in Central and Southern Europe, with especially severe impacts in Mediterranean areas. The European Environment Agency (EEA, 2024) forecasts a reduction of 16% in the value of European agricultural production by 2050, with potential declines exceeding 80% in Mediterranean countries by the end of the century, highlighting the urgent need for effective adaptation strategies and targeted support policies.

Starting from this scenario, the present thesis aims to provide an in-depth analysis of the impact of climate change on the productivity of enterprises within the Italian agri-food sector, with particular focus on the ability of these firms to adapt and respond to emerging challenges. To this end, the work is structured into

three distinct articles that address different aspects of the issue by combining qualitative and quantitative approaches.

The **first article** is a systematic review of the scientific literature aimed at exploring the relationship between sustainability reporting and the economic performance of firms in the agri-food sector. Over the past decade, global phenomena such as globalization, technological innovation, and climate change have profoundly transformed the socioeconomic landscape, imposing a more integrated vision of corporate management. Companies are increasingly called upon to disclose not only their financial results but also their environmental and social performance, responding to the demands of a wide range of stakeholders. The literature review, conducted through scientific databases such as Scopus and focused on keywords including "*corporate social responsibility*", "*financial performance*", and "*agri-food sector*", reveals a complex and sometimes contradictory picture regarding the link between sustainability and economic outcomes, especially within the agri-food context. This represents a solid foundation for future research aimed at clarifying the role of sustainability as a competitive lever and value driver for companies.

The **second article** investigates the perception and management of climate risk among a sample of 41 Italian livestock farms. Through a structured questionnaire, it was possible to assess the level of awareness among entrepreneurs regarding the consequences of climate change and the strategies adopted to mitigate associated risks. The results show widespread awareness of environmental challenges, but also a lack of systematic and structured approaches to climate risk management. In many cases, firms adopt a "*wait and see*" strategy, rendering them vulnerable to sudden and extreme weather events, with potential negative impacts on production continuity and economic sustainability.

The **third article** focuses on the quantitative analysis of the impact of climate change—specifically the increase in temperatures and changes in precipitation patterns—on the productivity of a sample of 93 farms in Calabria specializing in citrus and olive oil production. Southern European regions, particularly the Mediterranean basin, are especially sensitive to the effects of global warming, with significant consequences for the profitability of typical crops. The analysis demonstrates a significant correlation between climatic changes and productivity decline, while also underlining the importance of regulatory interventions and public policies to support the transition toward more resilient and sustainable agricultural practices.

In conclusion, this work seeks to contribute to the understanding of the complex dynamics linking climate change, corporate management, and economic performance in the Italian agri-food sector, providing insights for the adoption of innovative strategies and the development of public policies aimed at fostering sustainable and resilient agricultural development.

PAPER I – Linking ESG performance and financial returns. A Systematic Review of the Literature Evidence: focus on agri-food sector

Abstract

This paper aims to analyse the relationship between non-financial reporting and corporate performance in the agri-food sector through a systematic review of the existing literature. Given the growing importance of sustainability and corporate disclosure, the paper focuses on investigating possible correlations between the non-financial information disclosed by companies and their economic and financial results. The objective is to provide a critical and up-to-date summary of the available scientific evidence, helping to clarify whether and to what extent non-financial reporting can influence or reflect corporate performance in this sector. The paper is divided into five main sections: i) an introduction that contextualizes the topic and defines its importance; ii) an in-depth review of the literature that analyses the most relevant studies and the main methodologies adopted; iii) a description of the methodology used for the selection and analysis of bibliographic sources; iv) a summary of the results emerging from the review; v) finally, the conclusions, which discuss the theoretical and practical implications of the results, highlighting limitations and possible directions for future research. This contribution aims to provide a comprehensive and critical overview, useful for both academics and professionals interested in the integration of sustainability and economic performance in the agri-food sector.

Keywords: non-financial performance, corporate performance, agri-food sector, sustainability, corporate social responsibility, financial performance.

Introduction

Over the last ten years, the issue of sustainability has become increasingly topical and has received considerable public interest (Gerber R., Smit A., Botha M., 2023).

The value of sustainability is now recognised as an element that is intrinsically linked to companies' economic and decision-making processes. This in order to achieve performance objectives that are no longer understood solely in terms of profitability, but also in terms of environmental, social and governance (ESG) factors.

According to Aureli et al. (2020), organisations and projects without a strong culture of sustainability are often inadequate and unsuccessful.

Studies conducted by Adams et al. (2022) have shown that the key to future business progress lies in the proper implementation of environmental, social and governance (ESG) issues in management and reporting processes.

This way to thinking has been driven, on the one hand, by businesses' growing awareness of the importance of responsible investment in terms of social and environmental impact, and, on the other hand, by consumers, public authorities, the media and shareholders demanding greater transparency of information (Martos-Pedrero et al., 2019).

Alareeni and Hamdan (2020) have shown that the failure to integrate ESG issues into companies' business processes can have a negative impact on reputation and brand value, leading to economic and financial instability for the company.

Therefore, in recent years, companies have shown a growing interest in sustainability issues and have begun to publish reports dedicated to this topic. These reports are known as *Corporate Social Responsibility Reports* (CSR) or *Environmental, Social and Governance Reports* (ESG). They are now recognised as fundamental tools for measuring and communicating companies' responsible initiatives, using of quantitative and qualitative indicators specific to each sector.

According to Climent et al. (2021), sustainability reports are a key indicator of companies' ability to generate sustainable financial returns in the long term and mitigate risks.

These reports also facilitate the investigation of the relationship between sustainable management and financial performance.

According to Habermann & Fischer (2021) and Cooper & Uzun (2019), there is a correlation between non-financial reporting and a company's economic performance.

However, the analysis of this correlation remains an open debate in the literature because, although most studies suggest a positive relationship between the two variables, other studies report a negative or no relationship.

These uncertainties encourage the academic world to explore this complex relationship in greater depth.

One factor that could explain the lack of unanimous consensus on the relationship between non-financial reporting and company performance is the variety of definitions of CSR and company performance, and the different measurement methodologies and models used to analyse this relationship.

In fact, corporate social responsibility is a concept that encompasses a variety of aspects, making it a complex phenomenon to observe and measure. This has resulted in a variety of definitions, which vary according to the authors' perspectives and interests, creating confusion about how to define it in the context of corporate management (Van Marrewijk M., 2003).

Its different dimensions are explained using numerous theories, points of view and reference frameworks.

While most studies rely on ethical, sustainability or social responsibility indices to measure corporate sustainability, some researchers have developed their own measurement scales.

Maignan et al. (2000), Surroca et al. (2010), and Perrini et al. (2011) have developed tools based on Carroll's model[1], which considers corporate social responsibility as a four-dimensional concept: economic, legal, ethical, and discretionary. According to this model, a socially responsible company must be profitable, comply with laws and ethical standards, and engage in discretionary activities that respond to the needs of society.

On the other hand, Bansal et al. (2005), Apostolakou et al. (2010) and Chow et al. (2012), referred to the perspective of sustainable development, which interprets social responsibility as a construct based on three dimensions: the economic, the social and the environmental. In this sense, a socially responsible company must not only achieve economic success but also contribute to social development and environmental protection.

Finally, Waddock S.A. (1997), McWilliams A. (2001), Luo J.M. (2017), Turker D. (2009), and Fatma, M. (2014) have developed their own measurement scales based on the well-known stakeholder theory, which argues that socially responsible companies must consider the interests of all groups directly or indirectly involved in their activities.

However, growing interest in these issues has led to a highly fragmented body of laws and new best practice rules, resulting in a loss of clarity in corporate communication (Belmin et al., 2023).

In light of the growing importance of non-financial reporting, this paper aims to analyse the agri-food sector to assess whether companies in the sector have effectively embarked on a path towards sustainability and related reporting. We intend to investigate the possible correlation between these practices and the performance results achieved by companies.

The agri-food sector is one of the sectors with the greatest environmental and social impact (World Wildlife Fund, 2022), arousing growing interest among consumers: 81% of them say they carefully consider sustainability issues when purchasing food products (Topp-Becker J., Ellis J.D., 2017).

Despite this, many companies in the sector do not have the resources or expertise to effectively monitor the impact of their activities on the environment and society, nor to communicate such information transparently to their stakeholders (Seguí-Mas et al., 2018). This critical issue is compounded by the lack of specific sectoral guidelines to support companies in developing clear, consistent and comparable non-financial reporting (Krueger et al., 2021; Siew, 2015).

[1] Carrol, A.B. A three-dimensional conceptual model of corporate social performance. Acad. Manag. Rev 1979, 4, 497–505.

This gap has only been partially filled by the guidelines issued by the Global Reporting Initiative (GRI) in 2021, which refer to the impact of the agricultural sector on the environment, society and corporate governance.

In this context, the objective of this study is to review the existing body of scientific literature on the relationship between non-financial reporting and corporate performance. The aim is to identify the key factors that can guide companies towards sustainable development.

1. Literature review

The current socio-economic landscape is characterized by growing dynamism and significant changes resulting from globalisation, technological innovation and climate change. This underscores the importance of analysing companies from economic social, environmental and governance perspectives.

Businesses, society and the scientific community have come to realise that integrated management of financial and non-financial aspects leads to concrete results in terms of medium- to long-term sustainability, as well as contributing significantly to risk mitigation (Maroun et al., 2018).

The importance of non-financial reporting is not a new concept, but in recent years it has gained increasing attention in the debate on sustainability and in subsequent developments in corporate governance practices (Maroun et al., 2018, Russell et al., 2017, Samkin et al., 2014).

This evolution reflects a change in the way corporate performance is assessed. It is becoming less and less linked exclusively to economic and financial indicators, and more and more oriented towards including social, environmental and ethical variables.

There is a growing awareness that corporate decision-making and the achievement of sustainable results in the medium to long term can no longer be based solely on financial data (Atkins & Maroun, 2015, de Villiers et al., 2014, Maroun et al., 2018).

The integrated management of financial and non-financial information is now considered essential to fully understand the risks, opportunities and overall impact of business activities.

At the same time, a larger number of stakeholders (consumers, investors, institutions and local communities) are becoming more aware of the social and environmental effects of companies. This growing level of awareness has led to a redefinition of the concept of corporate responsibility, with a shift from a reactive to a proactive approach, in which companies are not only required to report on their activities, but also to take an active role in creating sustainable value (Maroun et al., 2018, Russell et al., 2017).

According to Conca et al. (2021), the most recent research indicates that companies no longer view ESG reporting as merely opportunistic practice aimed at improving their image, but rather as a tool for legitimisation and accountability towards stakeholders. In this sense, the integration of environmental,

social and governance criteria into management processes reflects a cultural transformation that recognises the centrality of these dimensions in the creation of sustainable value.

This growing focus on ESG practices is supported by a significant number of studies that have analysed their impact on corporate financial performance. Empirical evidence suggests that adopting environmentally, socially and governance-responsible behaviour can strengthen a company's reputation and contribute positively to its economic performance (Conca et al., 2021, Khan et al., 2021, Lokuwaduge & Heenetigala, 2017, Peiris & Evans, 2010, Pirtea et al., 2021, Resmi et al., 2018, Roudaki, 2018).

However, although numerous studies have highlighted a positive relationship between non-financial reporting and corporate performance, other studies have found conflicting results, reporting negative or no relationships between the two variables. This heterogeneous scenario has stimulated academic debate, opening up new research perspectives aimed at investigating the conditions and factors that may influence this relationship.

According to Conca et al. (2021), non-financial reporting practices vary from sector to sector and from company to company.

Furthermore, the content of sustainability reports often depends on management choices, which can cause distortions in ESG reporting.

In this scenario, the agri-food sector, which is extremely diverse by nature, presents numerous challenges and opportunities in terms of non-financial reporting and sustainable development.

Therefore, it is crucial for companies to accurately identify the key aspects of their operations, so that they can recognise the factors that are essential for achieving sustainability and business performance objectives.

1.1. Agricultural sector

The agri-food sector is one of the most important sectors for the global economic system.

In this sector, interest in corporate social responsibility (CSR) has grown rapidly, driven by changes in lifestyle and consumer purchasing preferences, as well as the emergence of a new business culture that is increasingly attentive to the social and environmental impact of the agri-food system (Nazzaro et al., 2020).

Nowadays, consumers do not just consider the characteristics and quality of products when make a purchase; they also want to know about the origin of the raw materials, production methods used and the social and environmental impact of the entire production chain (Martos-Pedrero et al., 2019).

CSR is a particularly relevant issue in the agri-food sector for several reasons.

Firstly, the production process of the agri-food system is linked to the use of natural resources and, for this reason, has a significant impact on biodiversity and the environment (Cupertino et al., 2021).

Secondly, agri-food is closely linked to food security, an issue that has sparked widespread debate in recent years in relation to social welfare and public health protection (Soon & Baines, 2013).

Furthermore, traditional agricultural practices are often associated with significant environmental risks and, in many cases, unethical working conditions.

Biggs et al. (2006), Conca et al. (2021), Melin et al. (2014) and Rankin et al. (2011) have emphasized that this sector continues to have a negative impact on the ecosystem. Examples of this include excessive soil exploitation, the intensive use of water resources and the use of chemical pesticides. At the same time, situations of labour exploitation have emerged that have raised considerable social concerns.

This is reflected not only in the image of companies in the sector but also in economic terms and financial returns (Maroun et al., 2018, Melin et al., 2014).

In this context, agri-food companies are facing new ethical, social and environmental challenges that affect the entire production chain (Nazzaro et al., 2020).

Thirdly, the agri-food sector contributes to climate change, being responsible for around 30% of global greenhouse gas emissions (Lafont-Torio et al., 2023).

For these reasons, a growing number of consumers are demanding that companies in the sector engage in dialogue with stakeholders, communicating their commitment to sustainability in a transparent and reliable manner (Topp-Becker & Ellis, 2017).

According to Monteiro et al. (2023), in order to progress towards a sustainable agri-food system, it is necessary to be able to measure and quantify the impact of agricultural activities on the economy, the environment and society.

Companies in the sector are therefore expected to pay increasing attention to the management of sustainability-related risks and related reporting (Atkins & Maroun, 2015, Levkivska & Levkovych, 2017, Maroun et al., 2018, McKenzie et al., 2013, Panait et al., 2020, Pirtea et al., 2021, Vrabcova & Urbancova, 2021).

Numerous companies have begun to adopt more sustainable practices, accompanied by the publication of sustainability reports and ESG reporting (Ihlen et al., 2011).

In this regard, the European Directive on Sustainability Reporting (CSRD) has been issued, which aims to encourage companies in the sector to significantly reduce their environmental impact and promote a profound transformation in production methods and resource procurement.

Companies' adaptation to the Directive is not limited to mere compliance with regulatory requirements, but represents a genuine strategic repositioning, oriented towards sustainability and innovation.

However, despite the existence of relevant Directives and Regulations, there currently seems to be a lack of specific guidelines for the agri-food sector to support companies in communicating their social responsibility initiatives in a clear, transparent and reliable manner. The absence of a shared sectoral

framework also makes it difficult to ensure the comparability of sustainability reports between different companies (Belmin et al., 2023).

2. Historical Development: the origins of non-financial reporting

The common goal of corporate social responsibility and social innovation is the advancement of society (Szegedi et al., 2017).

In this context, non-financial reporting and disclosure of corporate social, environmental and economic responsibility can be seen as an element of innovation that contributes to the well-being of the community (Welford 2005).

To understand the research attributes that guided the selection of the sample in this study, it is useful to retrace the main stages in the evolution and development of non-financial reporting.

From the outset, the concept of sustainability has been strongly associated with the issue of climate change, gaining visibility at the United Nations Climate Change Conference held in Copenhagen in 2009.

Initially, the focus was on reducing greenhouse gas emissions, responsible use of natural resources and adaptation to the effects of global warming.

However, over the years, sustainability has taken on a broader meaning, extending to environmental aspects (such as biodiversity protection and waste management), social aspects (inclusion, human rights, working conditions), ethical aspects (transparency, anti-corruption) and economic aspects (long-term value creation, financial sustainability).

In their academic paper *"One Report: Integrated Reporting for a Sustainable Strategy",* Eccles and Krzus (2010) highlighted the growing public concern about climate change and global warming, showing in a graph the exponential increase in the use of the terms "*climate change*" and "*global warming*" in scientific publications (Figure 1).

Figure 1.1 – Increasing Use of the Terms *Climate Change and Global Warming*

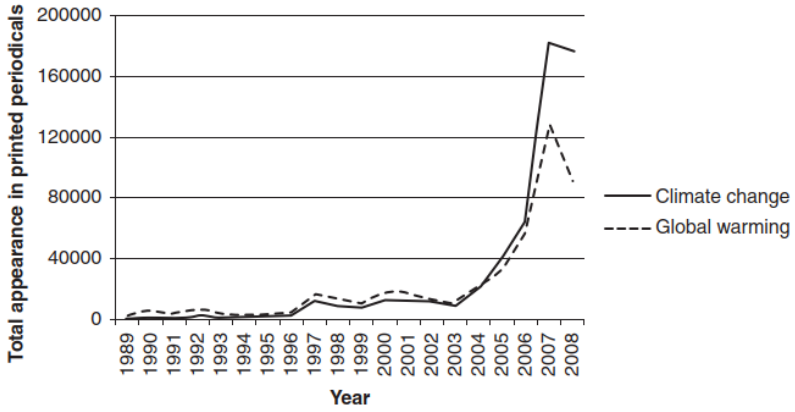

Exhibit I.1 Increasing Use of the Terms *Climate Change* and *Global Warming*, 1989–2008*

*We produced all of our "Increasing Use of the Term" figures using the Dow Jones Factiva database to measure the frequency with which the terms in question were used in all of the publications included in the database.

Source: One Report: Integrated Reporting for a Sustainable Strategy (2010).

The graph showed significant growth in 2004 and 2006, when interest in climate change began to involve not only the scientific community but also society at large.

Since then, companies have found themselves having to meet the information needs of an increasingly broad audience of individuals or groups interested in how they create value, and having to produce a wide variety of reports, with a consequent loss of clarity in corporate communication (Freeman 1984).

According to Shiller (2013), ESG information benefits both investors and society because financial markets are the main source of funding for social activities.

The main objective of ESG metrics is to reflect the performance of companies in relation to a specific objective.

Today, there are numerous and different non-financial reports, which have different titles depending on the reporting category to which they refer: "*Sustainability Report*", "*Social Responsibility Report*", "*Social and Environmental Report*" and "*Integrated Report*" (Stolowy and Paugam, 2018).

According to Waddock and Graves (1997), terms such as SRI (Socially Responsible Investing), CSR (Corporate Social Responsibility) and ESG (Environmental, Social, and Governance) are often used interchangeably in the literature to refer to the same area of study.

Due to this ambiguity in the use of terminology and the multitude of reports used for non-financial reporting, researchers do not unanimously agree on the specific role that ESG factors should play in corporate strategy.

Therefore, in the wake of growing interest among scholars and the need for industry operators to understand how companies act from a sustainability perspective, in 2010, the *Prince's Accounting for Sustainability Project and* the *Global Reporting Initiative (*GRI) established the International Integrated Reporting Council (IIRC) to create a *"globally accepted integrated reporting framework that brings together financial, environmental, social and governance information in a concise, consistent and* compatible format" (IIRC, 2013).

Today, ESG strategies have become a standard component for many medium to large companies around the world and can be either mandatory or voluntary.

As demonstrated by the Corporations Act (2001) and the National Greenhouse and Energy Reporting Act (2007), Australian public companies are required to disclose details of their environmental performance (Turzo et al., 2022).

Similarly, Chinese listed companies are required by the Securities Regulatory Commission to disclose information about their social responsibility (Turzo et al., 2022).

In Europe, EU Directive 2014/95 has imposed a change in the way large European companies disclose non-financial information, covering economic, social and environmental aspects. The regulation applies to companies with more than 500 employees and public interest entities, which must include information on their social, environmental, human rights and anti-corruption policies, risks and performance in their annual corporate reports. This regulation has affected more than 6.000 companies since 2017 (La Torre et al., 2022).

In South Africa, several mandatory regulations require companies to incorporate ESG factors into their reporting and governance practices. These mandatory requirements are primarily aimed at listed companies and certain large private companies.

In response to growing demand for transparency in ESG performance, many companies have voluntarily chosen to publish ESG reports.

However, according to Turzo (2022), operators and companies have yet to achieve consolidation and standardisation of the concepts and content of non-financial reporting.

In light of these considerations, it is essential to conduct an exploratory analysis of the existing literature in order to understand the approach that companies take towards sustainability and non-financial reporting.

Taking the agri-food sector as a reference, one of the sectors most involved in the transition to a sustainable economy, it is essential to address the issue of climate change, which is closely linked to corporate social responsibility in social, ethical and environmental terms. The goal is to verify whether companies in the sector have started reporting on their sustainability commitments and whether this practice is reflected in their economic results.

2.1. Recognised standards and frameworks for non-financial reporting

Although there are several methods of non-financial reporting, the literature has sought to identify reporting rules and standards.

These are guidelines that have been defined with the aim of simplifying communication on social, environmental, ethical and governance issues to stakeholders (Dumay, Guthrie, Farneti, 2010).

According to a survey conducted by KPMG in 2022 on the use of sustainability reports, the guidelines commonly used for reporting are: GRI (Global Reporting Initiative), TCFD (Task Force on Climate Change Related Financial Disclosure) and SDGs (Sustainable Development Goals).

Among these, the GRI guidelines are universally recognised and include the most information about the company (Dissanayake et al., 2019; Kuzey and Uyar, 2017; Siew, 2015).

This information provides an understanding of the organisation's profile and scope, providing the tools to understand its economic, social and environmental impacts (GRI, 2021).

The guidelines proposed by the GRI have been adopted by 78% of the 250 largest organisations in the world and 68% of the 100 top-performing companies in terms of turnover in 58 countries (KPMG, 2022).

Table 1.1 – GRI general disclosure

Content	**Strategy**
The organisation and its reporting practices	D 2-1 Organisational details
	D 2-2 Entities included in the organisation's sustainability reporting
	D 2-3 Reporting period, frequency, and contact point
	D 2-4 Restatements of information
	D 2-5 External assurance
Activities and workers	D 2-6 Activities, value chain and other business relationships
	D 2-7 Employees
	D 2-8 Workers who are not employees
Governance	D 2-9 Governance structure and composition
	D 2-10 Nomination and selection of the highest governance body
	D 2-11 Chair of the highest governance body
	D 2-12 Role of the highest governance body in overseeing the management of impacts
	D 2-13 Delegation of responsibility for managing impacts
	D 2-14 Role of the highest governance body in sustainability reporting
	D 2-15 Conflicts of interest
	D 2-16 Communication of critical concerns

	D 2-17 Collective knowledge of the highest governance body
	D 2-18 Evaluation of the performance of the highest governance body
	D 2-19 Remuneration policies
	D 2-20 Process to determine remuneration
	D 2-21 Annual total compensation ratio
Strategy, policies, and practices	D 2-22 Statement on sustainable development strategy
	D 2-23 Policy commitments
	D 2-24 Embedding policy commitments
	D 2-25 Processes to remediate negative impacts
	D 2-26 Mechanisms for seeking advice and raising concerns
	D 2-27 Compliance with laws and regulations
	D 2-28 Membership associations
Stakeholder engagement	D 2-29 Approach to stakeholder engagement
	D 2-30 Collective bargaining agreements

Source: GRI 2: General disclosures, 2021.

In July 2017, the Task Force on Climate Change Related Financial Disclosure (TCFD) published its final report, "*Recommendations of the Task Force on Climate-related Financial Disclosures*" (TCFD, 2017), providing a list of information relating to governance, strategy, risk management, metrics and targets that is essential for non-financial reporting.

These recommendations are voluntary and provide stakeholders with valuable information on climate-related risks and opportunities (Chua et al., 2022). Companies have the option of adopting them.

In fact, the guidelines proposed by the TCFD emphasise the disclosure of financial information arising from climate-related risks, rather than the company's direct impact on climate change (O'Dwyer and Unerman, 2020).

Table 1.2 – TCFD disclosure recommendations

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organisation's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organisation's businesses, strategy, and financial planning where such information is material.	Disclose how the organisation identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organisation has identified over the short, medium, and long term.	a) Describe the organisation's processes for identifying and assessing climate-related risks	a) Disclose the metrics used by the organisation to assess climate-related risks and opportunities in line with its strategy and risk management process.
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organisation's businesses, strategy, and financial planning.	b) Describe the organisation's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
	c) Describe the resilience of the organisation's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organisation's overall risk management.	c) Describe the targets used by the organisation to manage climate-related risks and opportunities and performance against targets.

Source: Task Force on Climate-related Financial Disclosures, Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures, 2021.

Finally, the SDGs identify 17 sustainable development goals based on a comprehensive integrated approach of 169 targets covering various interconnected sectors and topics (Diaz-Sarachaga, 2021).

Figure 1.2 – United Nations Sustainable Development Goals

Source: The 2030 Agenda for Sustainable Development, 2015.

The research methodology of this work is based on these considerations.

3. Research Method and data overview

That said, this paper aims to identify the most relevant topics in non-financial reporting, analysing their evolution over time and highlighting the main gaps in the existing literature.

To this end, a systematic literature review approach was adopted to identify the most significant publications relevant to the area of interest.

According to Pollock et al. (2021) and Munn et al. (2022), the results obtained through a systematic review allow not only to summarise the state of the art, but also to identify unexplored areas of research, thus providing useful guidance for future studies.

From the outset, Scopus was used as it is a comprehensive, multidisciplinary and reliable database that enables accurate searches of articles and publications in specific field or topic.

Scopus requires keywords to be entered into a search string and certain filters to be applied to refine the selection of documents.

The choice of keywords in this work was guided by the research objectives, including terms related to non-financial reporting, corporate performance and the agri-food sector.

An advanced search query was then developed using the Boolean operators *and* and *or*, applied to the Title, Abstract and Keyword fields (TITLE-ABS-KEY).

The query was as follows:

> *(TITLE-ABS-KEY (CSR reporting) OR TITLE-ABS-KEY (corporate social responsibility reporting) OR TITLE-ABS-KEY (sustainability reporting) AND TITLE-ABS-KEY (firm performance) OR TITLE-ABS-KEY (business performance) OR TITLE-ABS-KEY (performance) AND TITLE-ABS-KEY (agriculture) OR TITLE-ABS-KEY (agrifood sector) OR TITLE-ABS-KEY (food sector)) AND PUBYEAR > 2014 AND PUBYEAR < 2025.*

This initial extraction yielded a sample of 103 documents.

To increase the relevance and quality of the results, additional filters were applied:

- Document type: including scientific articles, reviews and conference proceedings, excluding editorial notes, books and other non-peer-reviewed documents.
- Language: only documents written in English.
- Subject area: the search was limited to three specific subject areas, Agricultural and Biological Sciences, Environmental Science and Business, Management and Accounting, in order to ensure the relevance of the contributions to the subject of study.

The filtered results were subjected to a relevance analysis in order to select only those studies that link CSR reporting to corporate performance in the agri-food sector, addressing issues related to climate change and sustainability strategies.

This methodology made it possible to identify a selected corpus of 60 recent studies consistent with the research objectives, forming the basis for a critical and up-to-date review of the interaction between CSR reporting and corporate performance in the agri-food sector.

Table 2.1. – Search strategy of both the initial and final search.

	Initial search	**Final search**
Database	Scopus	Scopus
Search string	CSR reporting; firm performance; agri-food sector	(TITLE-ABS-KEY (CSR reporting) OR TITLE-ABS-KEY (corporate social responsibility reporting) OR TITLE-ABS-KEY (sustainability reporting) AND TITLE-ABS-KEY (firm performance) OR TITLE-ABS-KEY (business performance)

		OR TITLE-ABS-KEY (performance) AND TITLE-ABS-KEY (agriculture) OR TITLE-ABS-KEY (agrifood sector) OR TITLE-ABS-KEY (food sector))
Filter	None	Applied
Document type		Article, Review; Conference paper
Language		English
Subject		Environmental Science; Business, Management and Accounting; Agricultural and Biological Sciences
Excluded		
Search date	2015	2015 – 2025
Results	103	60

Table 2.2 – Inclusion and exclusion criteria.

Inclusion Criteria	**Exclusion Criteria**
– Articles written in English – Selected period: 2015 – 2025 – Article, review and conference paper – Type of publications: Only studies that explicitly link CSR reporting to business performance in the agri-food sector and address issues related to climate change and sustainability strategies were selected.	– Type of publications: editorial notes, books and other non-peer-reviewed documents

The results show a greater concentration of studies in European countries: the United Kingdom ranks first, followed by Italy, the Czech Republic, Spain and Germany, suggesting that the issue of non-financial reporting in the agri-food sector is particularly relevant in contexts where sustainability and non-financial reporting practices are more established.

However, the presence of countries such as Indonesia and India, despite having fewer publications, also indicates a growing interest in emerging contexts.

Conversely, the low representation of large countries such as the United States and China could represent an area for further study in international literature.

Finally, Australia and Canada, known for their developed economies and the importance of the agri-food sector, occupy prominent positions in the distribution of documents, highlighting a significant commitment both in academic research and in CSR reporting practices. This reflects their strong focus on sustainability and corporate social responsibility in the sector.

Table 2.3 - Countries with the highest number of publications

Countries with the highest number of publications	Number of publications
United Kingdom	9
Australia	8
Italy	7
Canada	6
Indonesia	5
Czech Republic	4
Spain	4
Brazil	2
Germany	2
India	2

3.1. Thematic Development

The analysis of the results shows a growing focus on sustainability in the agri-food sector; however, evidence regarding the effectiveness of reporting practices in improving business performance still appears to be conflicting and poorly established. The literature focuses mainly on the European context, while showing a growing interest in specific sectors, such as the meat supply chain. To explore the state of the art on the subject of this study, the main scientific publications were examined and selected based on their relevance to the topic in question. This was done to identify emerging trends and the main gaps in research.

Table 2.4 – Publication with the highest relevance

Document title	Authors	Source	Years	Citation
Sustainability reporting practices of Hungarian food subsector from EU taxonomy perspectives	Gombkötő, N., Hámori, J., Rózsa, A., ... Lámfalusi, I., Kacz, K.	Discover Sustainability	2025	1
Sustainable performance of the largest global food companies	Santos, G.R., Seabra, J.M., Figueiredo, M.V.S., Vincenzi, T.B.D.	Revista De Gestao, 32(2), pp. 99–111	2025	0

Environmental issues in the food and beverage sector: a multivariate regional analysis	Gallego-Álvarez, I., Amor-Esteban, V., Martín-Gallego, E.	Applied Geography, 177, 103566	2025	0
A systematic review of the SAFA framework in the literature: An approach to assess sustainability in agri-food systems	Zarbà, C., Gravagno, R.M., Chinnici, G., Scuderi, A.	Cleaner Environmental Systems, 16, 100267	2025	2
Regulatory impact on the sustainability information of Mexican and Spanish agri-food sector: an exploratory analysis	Anguiano-Santos, C., Cárdenas, R.M.	Food Studies, 15(1), pp. 43–66	2025	0
A comprehensive framework for assessing circular economy strategies in agri-food supply chains	Veloso, V., Santos, A., Carvalho, A., Barbosa-Póvoa, A.	Environment Development and Sustainability	2025	0
Bridging the gap in sustainability measurement and reporting for agroecosystems: overview and development of an adaptive sustainability assessment and monitoring framework	Ibrahim, M., Krishna, B.K., D.G. Fraser, E.	Ecological Indicators, 170, 113091	2025	0
Halal food sustainable traceability framework for the meat processing industry	Bachtiar, W.F., Masruroh, N.A., Asih, A.M.S., Sari, D.P.	Journal of Islamic Marketing, 15(11), pp. 2759–2784	2024	5
Sustainable strategies and value creation in the food and beverage sector: the case of large listed European companies	Gazzola, P., Pavione, E., Amelio, S., Mauri, M.	Sustainability Switzerland, 16(22), 9798	2024	4
Achieving corporate carbon neutrality: a multi-perspective framework	Boiral, O., Brotherton, M.-C., Talbot, D.	Journal of Cleaner Production, 467, 143040	2024	8
Considerations regarding environmental performance from the perspective of sustainability	Safta, A.S., Popescu, L.	Environmental Engineering and Management Journal, 23(3), pp. 599–605	2024	1

Studies conducted by Gombkötő et al. (2025) have demonstrated a growing focus on sustainable reporting in the Hungarian food sector from the perspective of the EU taxonomy, reflecting the importance of aligning business practices with European environmental standards.

At the same time, the assessment of the sustainable performance of large food companies, as demonstrated by the studies of Santos et al. (2025), reveals an increasing adoption of sustainable strategies on an

international scale. However, challenges concerning measurement and reporting persist, as emphasised by Ibrahim et al. (2025) in their proposal for an adaptive framework for agroecosystems.

In this context, the importance of systematic and multidimensional approaches, such as the SAFA framework analysed by Zabrà et al. (2025), emerges, allowing sustainability to be assessed across different dimensions. At the sectoral level, Bachtiar et al. (2024) addressed the issue of sustainable traceability in the halal meat supply chain, demonstrating the importance of the practical application of these principles to specific sectors.

Furthermore, the literature highlights the importance of adopting circular strategies and achieving carbon neutrality (Veloso et al., 2025; Boiral et al., 2024) to mitigate the environmental impact of the sector. Meanwhile regional studies, such as that conducted by Gallego-Álvarez et al. (2025) emphasise the existence of geographical variations in environmental issues, thereby reinforcing the significance of a contextualised approach. Overall, these contributions outline an evolving landscape in which sustainability in the agri-food sector is addressed through integrated models, emerging regulations and technological innovations. These are all fundamental to the transition towards more resilient and responsible food systems.

4. Blind Spot and Conclusion

The analysis identified the historical factors that led to the development of non-financial reporting, highlighting the main thematic areas and sectors in which researchers have conducted the most important research.

Despite the growing focus on sustainability and the consequent proliferation of methodological frameworks for non-financial assessment and reporting, the relationship between these practices and the actual improvement of corporate performance remains unclear and characterised by significant ambiguity. While recognising the potential of sustainability reporting as a governance and communication tool, the existing literature often offers fragmentary and sometimes conflicting results regarding its ability to translate into tangible benefits, such as improvements in the financial, operational or reputational performance of companies. This uncertainty is accentuated by the lack of longitudinal and comparative studies that can clarify the conditions and mechanisms through which sustainable reporting impacts corporate dynamics.

Furthermore, when the focus narrows to the agri-food sector, the number of studies exploring this link is significantly reduced, despite the central role of this sector in global sustainability processes. The agri-food sector is characterised by a significant environmental impact, complex production chains and growing regulatory and social pressure towards more sustainable practices, making it a prime area for the application and development of non-financial reporting tools. However, the absence of established literature

specifically addressing how sustainability reporting influences corporate performance in this sector represents a significant gap. This lack of knowledge limits the ability of stakeholders — including managers, investors, and policymakers — to make informed decisions and develop effective strategies for the transition to more sustainable production models.

Furthermore, the predominance of studies focused on specific geographical contexts, particularly European ones, leaves open the debate about the possibility of generalising the results to different contexts characterised by different economic, regulatory and cultural conditions. This highlights further scope for future research that could explore how contextual variables influence the link between sustainability reporting and corporate performance in the agri-food sector. Overall, these elements indicate ample room for development in the field of study, suggesting the need for more rigorous methodological approaches and in-depth empirical analyses that contribute to clarifying the strategic role of non-financial reporting as a lever for competitiveness and social and environmental responsibility of agri-food companies.

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PAPER II – Climate change risk management and firms' adaptive responses: evidence from the livestock industry

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Abstract

Building on the existing literature on corporate risks management and emerging risks, this study investigates livestock firms' identification, assessment, and management of climate change risks. Specifically, we surveyed a sample of 41 Italian firms operating in the upstream stages of the livestock supply chain, to explore their perception of and responses to climate-related threats. Our findings reveal that, while being well aware of potential climatic challenges, the sampled firms have not adopted a systematic approach to climate change risk assessment and management. Furthermore, results suggest that Italian livestock firms tend to enact a wait and see strategy, along with adaptation measures when faced with unexpected disruptive events due to changes in the natural environment. On the whole, our study contributes to the ongoing debate on climate change risk by shedding light on firms' reactions to unpredictable uncertainties and by exploring the role of industry- and entity specific characteristics in shaping risk responses.

Keywords: climate change risks, livestock firms, adaptation measures.

1. Introduction

Risk and risk management have been extensively investigated by the academy under multiple perspectives (Heckmann, 2015). Although variously conceptualized, risk may be broadly defined as the likelihood of the realization of negative effects of an event or activity under uncertain conditions (Aven, 2016).

The growing levels of complexity and uncertainty characterizing the current business environment have significantly modified the breadth and scope of firms' risk, as well as risk management boundaries, prompting scholars to explore deep uncertainties and emerging risk characteristics and consequences (Ansell & Boin, 2019 Flage & Aven, 2015). Indeed, the occurrence of major disruptions in the last decades has raised concerns on the capability of traditional risk assessment and management techniques to predict and cope with severe threats. Particularly, it has been argued that the novel nature of emerging risks may

hamper management's ability to identify firms' vulnerabilities as well as decision-making, thus revealing the need for organizations to develop resilient attitudes to deal with unexpected, unfavorable events calling for adaptation and amelioration strategies embedded in organizations' general risk management systems (Sejian, 2015).

In this scenario, increasing attention is paid to climate change, as the impact of climate shifts due to greenhouse gas emissions generates new risks for natural and human systems (Dow et al., 2013; Fauzy et al., 2020), classified by the EU Commission (2019) as physical risks, i.e. risks from the physical effects of changing climatic conditions, and regulatory, technological and market risks, arising from transition to a sustainable, low-carbon economy.

While firms' role in actively contributing to climate change has been widely examined and regulated at both the local and the international level (Mottet et al., 2017; Havlík et al., 2014), more recent organizational studies have started to focus on their exposure to climate-related physical risks that threaten business activities and performance (Sakhel, 2017). In this regard, extant literature reports that companies tend to overlook physical and market consequences of climate change, but also that measures and actions adopted to minimize climate-related risks are sparse and diversified, depending on industry- and entity-specific characteristics (Sakhel, 2017).

Among the industrial sectors most affected by climate change, firms in the livestock supply chain are becoming a major concern not only because of the negative impact of their business activity on the natural environment (Wreford & Topp, 2020; Rojas-Downing et al., 2017), but also due to their key role in food supply and food security (Godde et al., 2021). On the one hand, the industry accounts for the 14.5% of global greenhouse gas emissions (Lazarus et al., 2022), this exposing firms to both regulatory and market risks. On the other hand, livestock companies' production processes are severely affected by climatic changes and, therefore, subject to physical risks further escalated by the strong interrelation among upstream and downstream entities of the supply chain. In this regard, while there is growing awareness on the effects of climate change on food production (IPCC 2014) – mainly driven by natural disasters and changes in precipitations, sea, and temperature levels – poor evidence exists on livestock companies' assessment and management of climate change risks. To the best of our knowledge, research on responses of livestock supply chain firms to climate-related exposure mainly focus on mitigating strategies devoted to the reduction of emissions or on adaptation strategies undertaken by firms operating in developing countries (Thornton & Herrero, 2014; Rivera-Ferre et al., 2016), whereas little is known on entities' ability to predict, evaluate and handle physical risks, especially in advanced countries.

Building on organizational literature on corporate risk management and emerging risks, our study aims to explore livestock firms' identification, assessment, and management of climate change risks. Specifically, prior studies testify that, although companies acknowledge climate change issues severity, they nonetheless tend to overlook and downplay climate-related risks, mainly complying with regulations and underestimating other potential negative consequences on the production process side (Manning et al. 2015). In addition, scholars point out that, among entities specificities, the firms' size may play a crucial role in shaping firms' responses due to the expensiveness of investments needed to cope with climate

change threats (Pant, 2011; Sussman et al., 2014). We therefore argue that, especially for SMEs, while an adequate level of acknowledgement of climatic exposure can be expected, practices adopted to face climate change effects and reduce GHG emissions may be mainly reactive and aimed at minimizing climate-related unfavorable impacts (Ghadge et al., 2020).

We thus develop the following research questions:

RQ1: Do firms in the livestock supply chain perceive and identify climate change risks?

RQ2: Which measures are adopted by firms in the livestock supply chain to assess and manage climate change risks?

RQ3: Do firms in the livestock supply chain integrate measures against climate change risks into their risk management system?

To address our research questions, we follow an established route of investigation in climate change literature and, consistent with previous studies (Schuldt et al., 2015; Sakhel, 2017), we survey a sample of 41 Italian livestock supply chain firms operating in the supply and production stages. Supply chain downstream companies, such as abattoirs and retailers are excluded from our sample in light of the different climate change effects impacting their business activity. We focus on the Italian livestock sector as interesting research setting because of the effect exerted by on climatic risk management by both the supply chain high interrelatedness and the distinctive characteristics of the firms in the industry, with prevailing micro and small sized sole proprietorships and partnership companies (ISTAT, 2022).

Our exploratory study provides several theoretical contributions. First, we respond to the call that companies' identification, assessment and management of climate change risk needs to be explored beyond the investigation of mitigation strategies. Second, by providing evidence of livestock firms' perception of and responses to climate-related challenges, we add to the extant literature on emerging risks and adaptation strategies. Last, to the best of our knowledge, no previous study has examined climate-related risks in the Italian livestock industry: due to its peculiar characteristics in terms of company size, organizational and governance structure, and supply chain interconnectedness, we contribute to the understanding of the role of context specificities in shaping firms' reactions to uncertainties and emerging risks.

The chapter is structured as follows: section 2 offers an overview of the extant literature. Section 3 describes our research setting and design. Section 4 presents our exploratory study results on livestock firms' identification, assessment and management tools related to climate change risks. Section 5 provides theoretical contributions and practical implications for both livestock supply chain managers and policymakers, also suggesting future research avenues.

2. Literature review

2.1. Deep uncertainties and emerging risk

The increasing complexity and uncertainty characterizing business operations at both the corporate and the environmental levels have brought risk and risk-management discourses at the core of scholars and practitioners' debate over the last decades, resulting in diversified theoretical and practical approaches (Heckmann et al., 2015). In this regard, although authors report the lack of a shared definition of risk and risk-related concepts, along with the heterogeneity and multifaceted nature of the conceptualizations provided over time and across fields (Fatemi & Luft, 2002; Noy & Ellis, 2003), there is a general consensus on the nature of risk (Aven, 2016).

From a qualitative standpoint, risk is generally conceived as "the likelihood of something undesirable happening in a given time" as a result of decision making (Merna & Al-Thani, 2008, p. 11), therefore encompassing three interrelated facets, i.e. adverse outcomes, the probability of their occurrence and a link between the two (Dow et al., 2013). Accordingly, since risk relates to future actions and their potential consequences in terms of outcomes considered as negative or undesirable (Aven, 2016), the growing number of uncertainties affecting the economic environment has advanced the debate on the scope and breadth of the concept of risk (Heckmann et al., 2015). Indeed, the enhanced dynamism, globalization, and interconnection of the business environment (Slagmulder & Devoldere, 2018) have deeply transformed the landscape of risk management leading to the emergence of borderless risks, at the same time modifying risk sources, severity, and diffusion across societal, organizational, and geographic boundaries (Smith & Fischbacher, 2009).

In light of changes occurring in firms' operating context, authors have hence started to investigate the impact of deep uncertainties and emerging risks on entities' forecasting and managing ability (Cox, 2012), as well as the cascading effect of risk at increasing levels of firms' interrelations (Smith & Fischbacher, 2009). Focusing on the first, a nascent line of inquiry explores the influence of deep uncertainties on risk assessment and management (e.g., Battanti & Lanati, 2022), as the high level of complexity related to both the "known and unknown unknowns" (Ansell & Boin, 2019) hinder decision-makers' ability to effectively predict potential future scenarios and evaluate alternative outcomes based on traditional techniques, such as stochastic processes and statistical analysis (Walker et al., 2013). Besides current risks, the recurrence of black swan type of events and mega-crises such as natural disasters, Covid-19 pandemic, and terrorism (Ansell & Boin, 2019), has led the academy to explore new threats having extreme or severe consequences on both natural and human systems, introducing the notion of emerging risk, conceived as: i) newly created risk; ii) newly identified/noticed risk; iii) increasing risk; or iv) risk becoming widely known or well established" (Flage & Aven, 2015, p. 61). More specifically, emerging risk refers to "a new (novel) manifestation of risk, of a type which has never before been experienced" (Locklear, 2011, p. 5), therefore encompassing new types of risks and/or familiar risks that become apparent in new and unexpected conditions (IRGC, 2010).

By centering on experience and familiarity, emerging risks definition emphasizes the role of weak background knowledge in hampering the identification of risky events and their outcome, at the same time revealing the need for dynamic risk assessment and management systems able to incorporate knowledge developments over time (Aven, 2016). Indeed, it has been argued that emerging risks tend to fall outside firms' usual cognitive and decision-making frameworks, as outlier events are often underestimated or disregarded due to the lack of previous experience (Locklear, 2011). In this perspective, as emerging risks are the byproduct of the interaction of cognitive, inter-personal and systemic forces (Roberto, 2002), their complexity may encounter cognitive impediments negatively affecting firms' information processing and foresight capabilities, thus calling for risk assessment and management systems based on cautionary and precautionary strategies, and early risk identification methods to read signals and warnings and translate them into adaptive and resilient approaches (Aven, 2016).

This is further strengthened by the intense firms' interdependence characterizing the current business environment: while, on the one hand, such feature allows for greater efficiency through outsourcing and synergistic value creation (Cao & Zhang, 2011), on the other hand it reduces economic systems robustness, as intercompany relationships tend to escalate and propagate the consequences of hazards to partner entities causing cascading effects on the entire network (Tang et al., 2006; Heckmann et al., 2015). In this regard, supply chain risk and its management have been extensively investigated, since supply chains increasing complexity and length jeopardize organizations' ability to adequately identify threats nature, likelihood, and severity and to consequently address the related containment activities (Tummala & Schoenherr, 2011), thus magnifying companies' vulnerability and the outcomes of negative events especially in a dynamic environment (Tang & Musa, 2011; Tang, 2006).

Although variously defined, supply chain risk may be interpreted as the likelihood and impact of unexpected events or conditions adversely affecting "any part of a supply chain leading to operational, tactical, or strategic level failures or irregularities" (Ho et al., 2015). While this may originate from various triggering events, it is reported that major supply chain disruptions emerge when macro-risks, described as man-made and natural catastrophic events (Sodhi et al., 2012), occur. Indeed, as emerging risks and deep uncertainties mainly materialize in globalized and complex contexts (Giddens, 1990), supply chain networks characteristics appear to increase the exposure to such threats. Furthermore, existing interconnections among supply chain companies tend to decrease firms' ability to identify risk factors and causal links, thus enhancing risk opaqueness (Batsakidis and Tsigkas, 2022) and lessening organizations' risk assessment and limitation ability. Therefore, the unpredictability of emerging risks along with supply chain complexity have led scholars to underscore the role of post-disruption measures (Pyke & Tang, 2010), as the unlikelihood of identifying all emerging risks in advance calls for adaptation strategies based on information acquisition to sustain decision-making (Batsakidis and Tsigkas, 2022). Indeed, coping with emerging risks require supply chain firms not only to adopt mitigating strategies, but also to absorb and adapt to disturbances, hence developing resilience and proactive, dynamic risk management approaches (Parker & Ameen, 2018). These, in turn, should be based on knowledge development and allow for

adjustments and responses to actual and expected effects of deep uncertainties and hazards arising in the business environment (Linnenluecke, 2013).

2.2. Climate change risk management

Among the different types of emerging risks and deep uncertainties, climate change risks are gaining momentum in organizational studies (Lee & Klassen, 2016), as a growing body of literature advocates that companies will be asked to cope with changes in climate conditions to an increasing extent (Weinhofer & Busch, 2013; Gasbarro & Pinkse, 2016; Pinkse & Gasbarro, 2019). Specifically, recent developments in global climate change underscore the key contribution of firms as emitters of greenhouse gasses (Kolk et al., 2008). At the same time, it is widely recognized that firms are also potentially affected by climate change effects, which require organizations to adopt risk response measures (Goldstein et al., 2018).

According to prior research, climate-related risks may be classified into three main categories, namely regulatory, market and physical risk (Sakhel, 2017): while the first arises from the augmented local and international regulatory activity to reduce firms' impact on climate, market risk relates to customers' demand variations and non-governmental entities' pressures towards a more sustainable management. Last, physical risk stems from changes in the natural environment, such as extreme meteorological events, drought, and floods (Pointner & Ritzberger-Grünwald, 2019).

Despite being aware of the potential negative consequences of climate change, companies are reported to underestimate them (Locklear, 2011) and to be far more concerned about compliance with regulatory requirements than about the exposure to market and physical risks, the latter being conceived as more distant in time and scarcely urgent (Manning et al. 2015). Particularly, previous studies testify that the number of companies adopting actions to minimize climate-related risk are relatively low (Reid & Toffel, 2009). Furthermore, it has been found that "the range of responses to climate change challenges has been very wide" (Aggarwal & Dow, 2012, p. 318), strongly depending on the type of risk as well as on industry- and entity-specific characteristics (Sakhel, 2017).

On the one hand, firms tend to handle regulatory and market risk by increasing decision-making information resources, lobbying regulatory bodies, and lowering emissions (Lazarus et al., 2022), while responses to physical risks are generally an integral part of firms' risk management approach and governed by adopting adaptation strategies (Ghadge, 2020), such as diversification and production relocation, and insurance coverage (Berkhout et al., 2006; Martin et al. 2014).

On the other hand, it has been found that firms' perceptions of and responses to climate change risk are influenced by the industrial sector in which they operate in terms of vulnerability to primary impacts of changes in the natural environment: indeed, businesses depending on seasonal and climate conditions or those most affected by infrastructures disruptions (Winn and Kirchgeorg, 2005) are more urged to respond to climate change threats. Similar conclusions may be driven for firms in deeply interconnected supply

chains, because of secondary impacts exerted by climate change exposure of upstream and downstream activities (Ghadge, 2020), such as resources supply and product distribution. For instance, extant literature provides evidence of the development of integrated strategies to deal with negative effects of climate change in agricultural, tourism, oil and gas and electricity (Weinhofer & Busch, 2013), together with transportation and logistics companies (Ghadge, 2020). In addition, several organizational and contextual factors may foster entities' ability to deal with climate-related risks, such as directors and senior management involvement, internal audit oversight (Trotman & Trotman, 2015), resource availability, geographical location (Weinhofer & Busch, 2013), industry affiliation, and previous experiences with such risks (Sakhel, 2017; Lawrence et al., 2014).

All in all, previous evidence confirms the heterogeneity of organizations' responses to climate challenges, also due to different management's perceptions and knowledge of potential consequences arising from changes in natural environment, that in turn lead to diversified and coexisting counteractions, referred to as mitigation, adaptation, and amelioration strategies (Sejian, 2015). While the first may be driven by both regulations on gas emissions and corporate reputation matters (Sakhel, 2017), the second refers to actions undertaken to reduce potential adverse effects of climate changes, thus depending on management beliefs and awareness: as climate change becomes a material issue, firms will progressively move away from wait and see and/or reactive strategies in favor of proactive approaches (Weinhofer & Busch, 2013). In this perspective, an integral part of organizations' response lies in amelioration, as a reactive response aimed at minimizing the impact of already occurred climate-related disruptions.

In this scenario, while acknowledging the profitable coexistence of different and contextual measures to deal with climatic exposure, academics have outlined that greater effectiveness could result from integrating such responses into firms' risk management system (Weinhofer & Busch, 2013), according to general risk management processes based on the three subsequent stages of risk identification, risk assessment in terms of risk potential impact and probability of occurrence, and risk response in the form of risk reduction, avoidance, and transfer (Merna and Al-Thani, 2008).

2.3. Climate change risk in the livestock food supply chain

The livestock food supply chain is especially vulnerable to climate change risks along various dimensions (Wreford & Topp, 2020; Rojas-Downing et al., 2017; Thornton & Gerber, 2010; Sidahmed, 2008). Indeed, the potential for climate-related impacts on livestock companies arises from the interplay between climatic hazards and the susceptibility and vulnerability of human and natural systems (Godde et al., 2021). As a result, meat industry firms play a dual role as they are both impacted by environmental issues and, in turn, they impact the natural environment due to their production processes.

On the one hand, it is widely recognized that the production processes of meat industry firms intensively affect the environment for several reasons (Djekic, 2015). First, meat production systems are found to be

inefficient in terms of nutrient and energy utilization, also having long conversion time before the meat can be transformed and distributed to retailers and consumers (Bhat et al., 2015). Second, land clearing for pasture, feed production, manure, and the methane emitted by the animals are considered to heavily contribute to greenhouse gas emissions, accounting for the 14.5% of global emissions (Lazarus et al, 2022).

On the other hand, besides meat industry negative environmental consequences, its exposure to climate change also originates from the effects of extreme weather events on livestock activities. This is further exacerbated by the high levels of interaction of livestock supply chain stages (Golini et al., 2017), with firms showing strong interdependencies due to economic pressures towards vertical and horizontal coordination (Fearne, 1998). Consistently, not only climate change events may involve the different stages of the supply chain, but their effects may also propagate from upstream to downstream entities thus magnifying their potential impacts. This interconnectedness can result in a cascade of negative consequences on the entire supply chain, including production, processing, distribution, and consumption of meat products, thus driving attention on the need to adopt a holistic approach to address livestock supply chain exposure and vulnerabilities (Gitz at al., 2016).

In this respect, risk identification, assessment and management in the supply chain is made more difficult by the breadth of natural, human and societal implications potentially arising from climate-related negative effects: indeed, the livestock industry plays a key role in food supply and food security, and as a source of nutrients for poor soils together with income generation and diversification, therefore contributing to communities' wealth and resilience (Godde et al., 2021).

According to Godde et al. (2021), climate change events most impacting the livestock supply chain basically relate to four types of hazards, namely atmospheric CO_2, tropospheric O_3, temperature and precipitations, along with storm surges and sea level rise. Based on this, the authors analyze firms' exposure to climate change risks relating to each livestock supply chain stage, i.e. fodder supply, breeding, industrial processing and distribution, consumption (Golini et al., 2017).

Supplier and breeding firms are reported to be exposed to threats related to feed and water. Focusing on the first, while gas emissions may both positively and negatively affect livestock feed, changes in temperature and fields dryness exert an overall adverse effect as high temperatures not only reduce crops and pastures yields, but also tend to dehydrate them, thus favoring the concentration of toxic secondary compounds and lowering feed quality (Godde et. Al., 2021). Furthermore, warming temperatures along with drought periods, heavy rains, and greater humidity increase phytopathogens and soil contaminants concentration, while reducing pollinators availability. Similar to feed, the effects of water availability extend to the different stages of the livestock supply chain, as its use spreads from growing crops and animals to the production of fertilizers, pesticides, electricity and fuel (Godde et al., 2021).

Focusing on animal health and production, immediate and long-lasting climate change effects relate to physiological, metabolic, and behavioral consequences (Filipe et al. 2020; Gauly & Ammer, 2020;). Warming temperatures cause animal heat stress, both on farm and during transportation, with outcomes that depend on animal species, breed, life stage, genetic potential, nutritional status, size, and level of

insulation (Saeed et al., 2019). This, in turn, is found to negatively affect animals' feed intake and productivity, welfare and survival, as well as to lower immune functions (Nardone et al., 2010) and the effectiveness of some vaccines (Godde et al., 2021), hence increasing the incidence of livestock disease.

Temperatures also negatively impact product processing, distribution, and storage, potentially causing degradation of food quality and shelf-life, along with augmented wastage, whereas extreme weather conditions may damage transportation infrastructures, hence limiting the distribution of products. This, in turn, fosters the likelihood of the proliferation of microbes, especially under humid conditions (van der Spiegel et al., 2012), making livestock products less appealing to customers, reducing meat quality and provoking the dissemination of enteric pathogens from livestock into human food. Such consequences are further worsened by changes in dietary preferences of consumers and societal concerns on labor conditions, animal welfare and environmental issues, especially in high-income countries that, together with physical risks and in light of livestock industry concentration and coordination, may enhance climate-related effects throughout the supply chain (Pais et al., 2020).

Despite the clear identification of climate-related risks affecting the livestock supply chain, very few studies explore the supply chain responses to climate change risks under an organizational perspective, with most contributions focusing on livestock firms' mitigation strategies in terms of reduction of greenhouse gasses emissions (Chiriacò et al., 2021; Mottet et al., 2017; Havlík et al., 2014). First, to the best of our knowledge, little research exists on physical risks assessment and management (Escarcha et al., 2018), as studies mainly list and analyze physical risks categories affecting the livestock industry or investigate adaptation responses in developing countries (Kabubo-Mariara, 2008; Rust & Rust, 2013; Thornton & Herrero, 2014; Rivera-Ferre et al., 2016). In this regard, extant literature testifies that adaptive responses through technical and management improvements, such as increasing feed quality, irrigation efficiency, alleviating heat effects, and changes in livestock species, are the most widespread measures enacted by livestock firms (Henry et al., 2018; Mu et al., 2013; Mirza, 2003), while systemic adaptation appear to be less common (Escarcha et al., 2018).

Second, although previous research theoretically confirms that climate variability may be managed by integrating mitigation, adaptation and amelioration strategies, concerns arise on their actual implementations due to firms' low perception of climate change threats and limited resources as opposed to the expensiveness of such strategies (Pant, 2011; Sussman et al., 2014).

Based on the above, we develop the following research questions accordingly to the risk management system stages, i.e. identification, assessment and management (Merna and Al-Thani, 2008):

RQ1: Do firms in the livestock supply chain perceive and identify climate change risks?

RQ2: Which measures are adopted by firms in the livestock supply chain to assess and manage climate change risks?

RQ3: Do firms in the livestock supply chain integrate measures against climate change risks into their risk management system?

3. Research setting, methodology and sample

The Italian food industry is a particular interesting research setting, as it reveals several distinctive traits that influence its reputation and competitive advantage worldwide, as well as supply chain dynamics. According to Coldiretti[2] and Unione Italiana Food[3], the agricultural and livestock industry has been recognized as: being the "greenest" agriculture in Europe, with 316 PDO/PGI/TGS[4] certified specialties recognized at the EU level; the leader in the organic sector with over 80,000 organic farms; having a varied population of both multinational enterprises and micro-, small- and medium-sized enterprises, mutually interdependent and cooperating for production purposes (Sadeghi and Biancone, 2018); adopting innovative techniques, resilience, inventiveness and investments in sustainability (Capitanio et al., 2009).

In this scenario, while few data on the Italian livestock supply chain have been published, several industry reports are presented by Italian trade associations and ISTAT (Italian national institute of statistics) on the agricultural sector. Particularly, in 2020 it comprised 1,133 million firms, of which 27% in the North, 16% in Center and 57% in the South of Italy. From an organizational standpoint, 98.3% of agricultural and livestock firms are sole proprietorships (93.5%) or partnership companies (4.8%), whereas limited liability companies and agricultural cooperatives respectively amount to 1% and 0.3% (ISTAT, 2022). Consistently, most of the industry entities are micro enterprises (98.6 %), averagely employing up to 10 workers (ISTAT, 2022) and with average total revenues of about 66,836 euros (RICA, 2020). Among agricultural companies, livestock firms account for 29% of the total national agricultural production. As of 1 December 2020, in Italy there were 246,161 livestock firms, i.e. 22% of agricultural entities. in terms of firms' geographical distribution, most livestock firms are in South and North Italy (respectively, 41% and 39%), while Center-Italy regions account for 20% (CREA, 2021).

Regarding the number of animals raised, there were about 22.3 million animals raised on 1 December 2022, of which 8.7 million pigs,1 million goats, 6.6 million sheep, and 6 million cattle and buffaloes. The largest contribution of farmed animals goes to the North-East, where half of all the registered animals is found. In this distribution, poultry and rabbits reach the highest stocks in Italy, with a good contribution also of cattle and pigs.

To address the research questions, our exploratory study relies on a survey of a sample of 41 Italian firms operating in the upstream stage of livestock supply chain, i.e. fodder suppliers and breeders. This approach is consistent with previous studies (Berkhout, 2006; Sakhel, 2017; Schuldt, 2015), as questionnaires have

[2] Coldiretti – Coldiretti, is a non-profit organization, which represents agricultural enterprises, direct growers, professional agricultural entrepreneurs, agricultural companies, fish businesses and entrepreneurs, consortia, cooperatives, associations and any other entity and subject operating in the agricultural, fisheries, agri-food, environmental and rural sectors, at national, European and international level.

[3] Unione Italiana Food - Unione Italiana Food is the leading association in Italy for direct representation of food product categories and among the first in Europe. An associative "house" whose mission is the enhancement and protection of companies, products and sectors which are among the excellences of our industry, and which are called to new challenges every day on markets all over the world.

[4] PDO - protected designation of origin; PGI - protected geographical indication; TSG - traditional specialties guaranteed.

been defined as an information gathering tool, allowing to investigate several issues simultaneously (Zammuner, 1996). Therefore, this research technique appears to be consistent with our research objective, i.e. shedding light on climate change risk identification, assessment and management practices of livestock supply chain firms. Furthermore, we excluded downstream companies, such as abattoirs, distributors, and retailers, because of the heterogeneous climate change threats affecting their businesses compared to the upstream ones.

The questionnaire was conducted on Google Forms, with a first section aimed at understanding livestock firms' identification of climate-related threats (RQ 1), and a second section investigating their climatic risk assessment and management measures (RQ 2 and RQ 3). More in detail, the first section aims to collect general information on respondents' demographic characteristics, such as the company's age, geographical location, size (in terms of employees' number and total revenues), and business activity. In addition, questions were asked on firms' risk identification in terms of awareness and perception of climatic threats materiality, aiming to provide further insight into climate risks typologies exerting greater impact on the supply chain companies. The second section of the questionnaire purposes to assess whether the sampled entities have adopted specific climatic risk assessment and management strategies and, if so, to what extent such management system distinguishes the short-terms and the long-term risks, together with direct and indirect climate change impacts. Last, the survey also aims to assess companies' approach to the evaluation of the financial impact of climate change effects and to the implementation of adequate planning and control measures to counteract climate change risks. Moreover, the questionnaire also intends to understand whether livestock enterprises have identified *ad hoc* functions responsible for the climate change risks evaluation.

The questionnaire consists of 44 questions, and it was structured using multiple choice, Likert scale and open-ended questions. To obtain a large and varied sample, the questionnaire was sent both Confagricoltura (the Italian agricultural firms association) and AIA (the Italian association of breeders), which then proceeded to disseminate it to their members. The survey was first proposed in January 2023, and final responses were collected in February 2023, after one reminder email. Overall, 52 responses were received: following the exclusion of those sent by firms' not operating in the livestock supply chain, our final sample consists of 41 livestock supply chain companies.

4. Findings

4.1. Sample characteristics and climate change risk identification

In terms of demographic characteristics, respondents' geographical distribution covers the entire national territory, although not homogeneously (Figure 1).

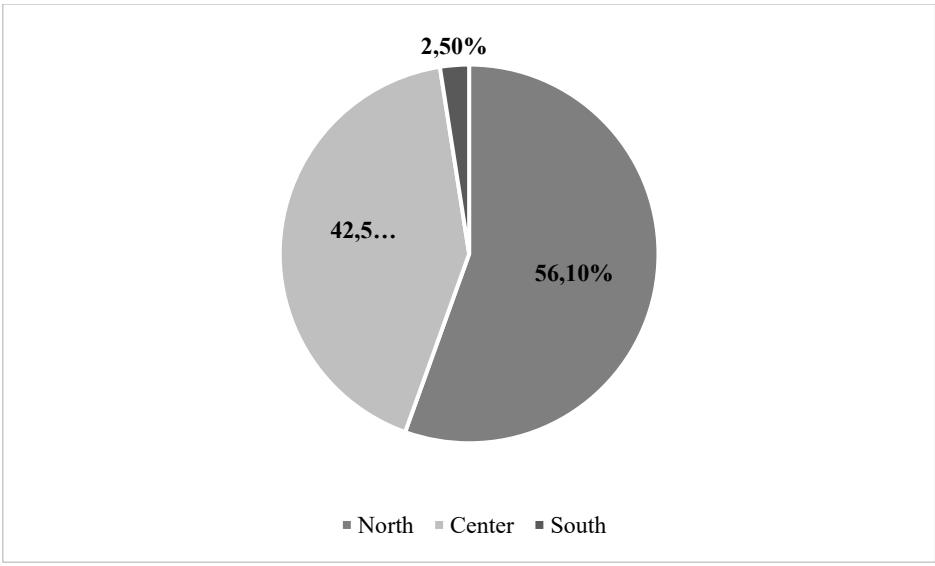

Figure 1 - Respondents' geographical distribution

Nevertheless, the sample characteristics appear to mirror those of the Italian firms operating in the upstream of the livestock supply chain, where sole proprietorships, micro and small enterprises prevail, as shown in Figures 2 and 3. This is further confirmed by respondents' average number of employees, as 85% of the sample firms employed up to 10 workers during the last financial year.

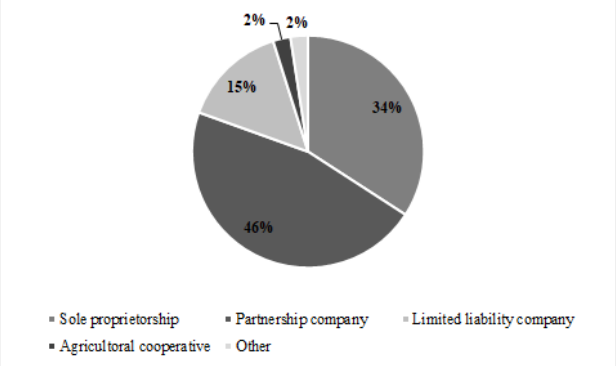

Figure 2 - Sampled firms' legal form

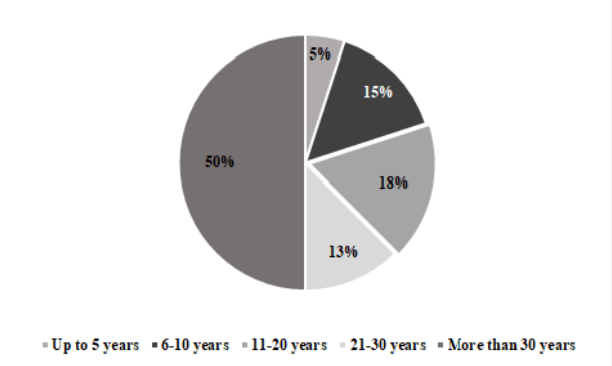

Figure 3 - Sample turnover.

In addition, 49% of the respondents are found to be longstanding firms with more than 30 years' experience (Figure 4), thus suggesting a strong knowledge of the business environment and industry dynamics that could support them in assessing and responding to climate-related risks, as familiarity with risks is found to positively influence risk perception levels and risk management capability (Lawrence et al., 2014).

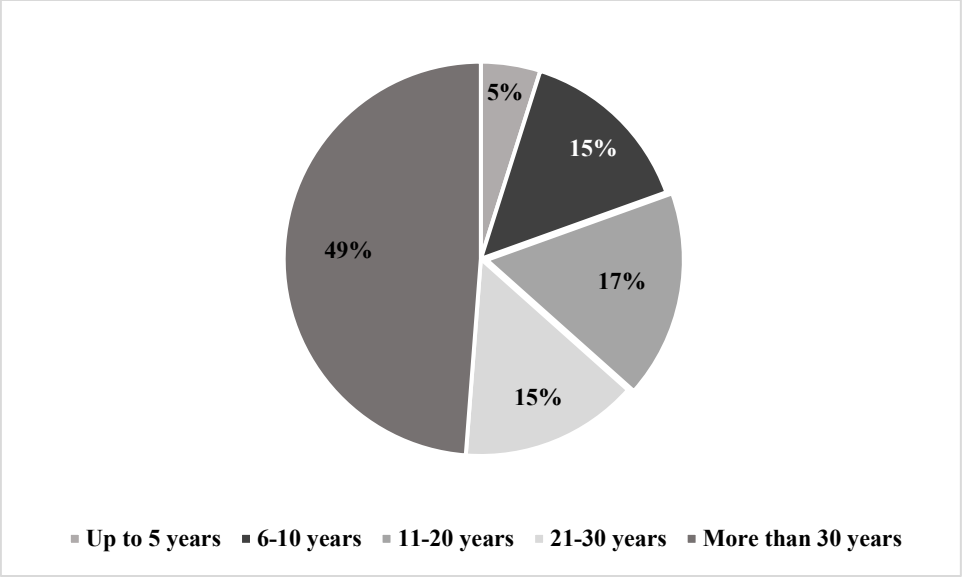

Figure 4 – Sample age

Focusing on the sample's business activity, the majority of the respondents belong to the agricultural production sector (87.8%), thus operating in the supply stage of the livestock supply chain, while only 12.2% are breeders. Despite previous studies reporting that risk identification, assessment and management approaches may be industry-specific (Sakhel, 2017), we found no significant difference in perceptions and responses provided by the two subgroups, perhaps due to the similarity of climatic threats affecting both of them and to the interconnectedness characterizing the supply chain (Fearne, 1998).

In terms of firms' awareness of climate-related challenges, responses provided by sampled firms reveal a widespread perception and knowledge of climate change risks that may affect their business.

Indeed, the majority of respondents (97%) perceive climate change as a current risk threatening their production processes and, more in detail, 83% conceive it as being a material issue to their business, whereas only two firms disagree on their exposure to climate-related events – namely a poultry breeder and a soy and corn grower – notwithstanding their previous experiences of climate negative impacts (Table 1).

	Strongly disagree		Disagree		Undecided		Agree		Strongly agree	
	No.	%	No.	%	No.	%	No.	%	No.	%
Climate change may be a risk for your business activity	0	0%	2	5%	0	0%	17	43%	21	53%
Climate change risk is a material risk for your business activity	0	0%	3	8%	12	30%	20	50%	13	33%

Table 1 - Climate change risks perception

On the opposite, most sampled firms appear to be aware of climate-related risks regardless of having previously suffered from climate-related negative consequences: in this regard, among those who acknowledge threats related to natural environmental changes, 78% declare to have faced earlier climate change effects, related to both draughts and rains (87%) and extreme weather events (9.7%). Specifically, most of the respondents cite Summer 2021 rise in temperatures of 1.5-2 degrees above seasonal averages and long periods of drought interrupted by violent rainfalls that destroyed crops and reduced crops yield, also causing severe stress to cows. In addition, one interviewee recalls the tragic event of the flooding in the Misa Valley, between Marche and Umbria, which last September, after six long months of drought, caused the Misa River to overflow, generating a "*tsunami effect*" with irreparable damage to agriculture and several victims. Furthermore, when asked about measures adopted to face these unexpected events, most entities indicate adaptation responses, such as increasing irrigations, changes in crops varieties and in seeding times, together with production activities reduction, while only two companies have opted for risk transfer through insurance coverage. Interestingly, when matching the sample's opinion on climate change risk with company's age, no relation between firms' expertise and risk perception emerges, in contrast with previous findings stating the positive impact of earlier experience on emerging risks responsiveness (Lawrence et al., 2014).

Focusing on direct risk categories identified as material to the surveyed firms' businesses, it is worth noticing that threats most recurrently cited are those related with crops yield (52.50%) and phytopathogens and microbes spread (25%), while a lower number of respondents report to expect climatic negative consequences related to fodder and meat quality (7.5%), animal stock reproductive capacity (7.5%), and products processing and storage (2.5%).

Similar results emerge when investigating major indirect risks expected to impact business activities by affecting the sample's suppliers and customers. On the first, respondents are mostly concerned of climate change threats related to crops yield (42.5%), pathogens spread (17.5%) and feed quality (7.5%); regarding the second, most cited risks involve crops yield (30%), pathogens spread (15%), customers' perceptions of products quality (10%), and products processing and distribution (10%). Smaller consideration is given instead to animal stock reproductive capacity (7.5%) and feed quality (2.5%). Quite surprisingly, no mention of threats about fodder quantity, soil contamination, and pollinators availability emerged (Godde et al., 2021).

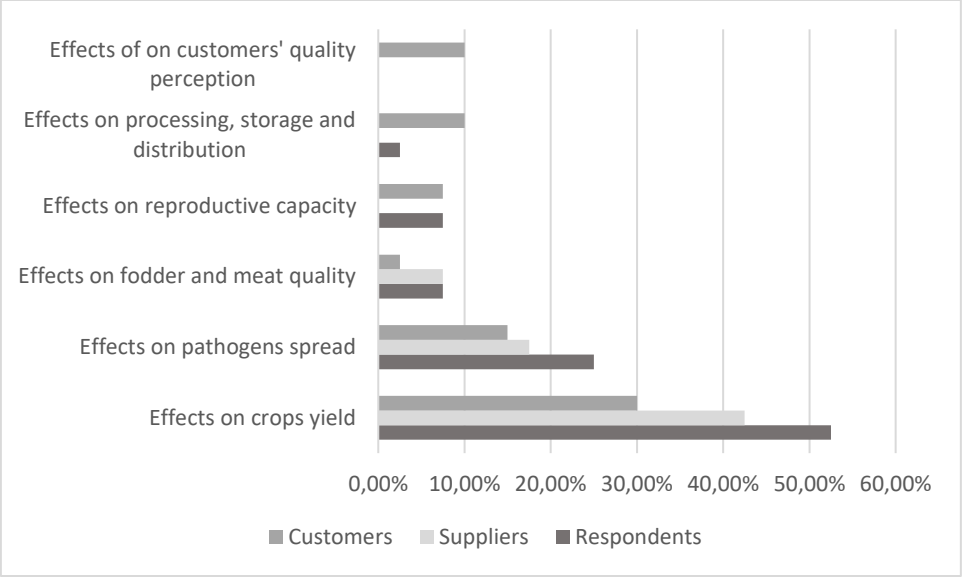

Figure 5 – Identification of climate change risks

Despite the widespread awareness arisen from questionnaire responses, only 55% firms maintain to know the European Climate Change Legislation (EEC/EU Regulation No. 1119 of 30 June 2021), which sets the binding goal of climate neutrality in the European Union by 2050, as well as the Italian regulation on climate change and greenhouse gas emissions, notwithstanding the cruciality of agricultural firms' active participation due to their role of emitters.

This is further confirmed when considering the drivers underlying the sample's increased awareness on climate-related threats over last five year, since only 5% of respondents ascribe their greater concerns to recent climate change regulation, as opposed to negative consequences of past climate-related disruptions (70%), or to both events (17.5%). Interestingly, such finding appears to contrast with the existing literature that identifies regulation on climate-related issues and greenhouse gas emissions as the key drivers of companies' responses to climate change challenges (Manning et al. 2015).

4.2. Risk assessment and management

Analyzing the questionnaire section devoted livestock firms' responses to climate change risks in terms of assessment and management systems, it is worth noticing that only about 40% of the respondents expect climate-related negative impacts to increase over the next ten years and report to have adopted measures to assess and/or manage climate-related risks.

Among the firms pertaining to this subsample, the vast majority (93.8%) relies on external sources to acquire information on climate change risks, consistently with scholars' call for compensating the lack of previous experience and the unpredictability of climatic threats (Aven, 2016) (Figure 6). Interestingly,

companies declare that the knowledge collected is then used in view of strongly diversified aims, namely supporting mitigation and/or wait and see strategies, adjusting agricultural and breeding techniques to climate-related changes, improving irrigation and cooling systems, along with corporate governance and strategic planning. Furthermore, one respondent specifies that knowledge acquisition is mainly aimed at gathering information on the short-medium term climatic challenges, thus confirming the tendency to neglect long-term consequences (Manning et al., 2015). In addition, new knowledge application to the business activity is significantly restrained due to the phenomenon newness and investments expensiveness (Pant, 2011).

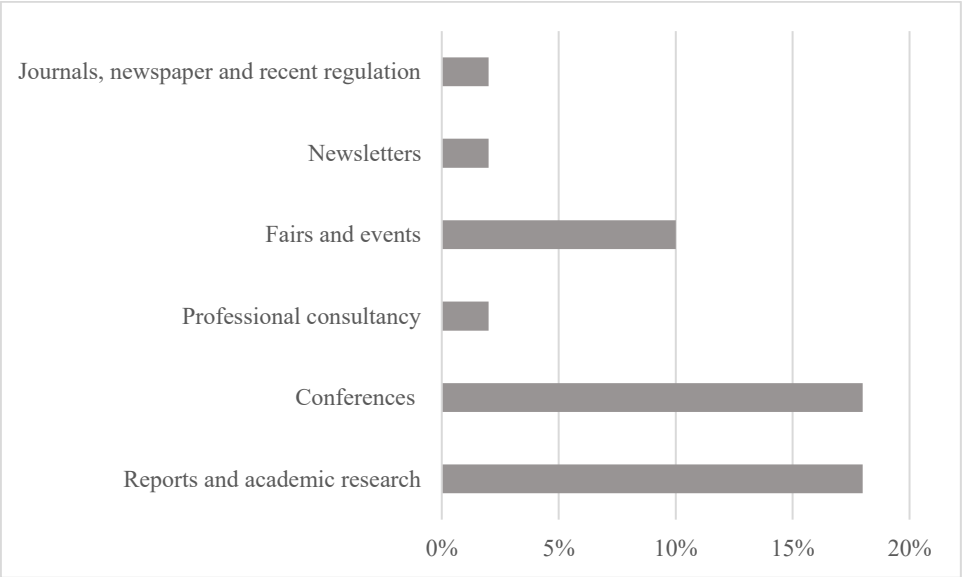

Figure 6 – Sample's external sources of information on climate change.

Although responses to the first section of the questionnaire testify firms' awareness and identification of climatic risks, answers provided to questions in the second section suggests that companies struggle to implement adequate risk assessment and management systems. In this regard, the whole subsample maintains to have adopted some forecasting method (Figure 7), although none of them supporting the evaluation of probability of negative future events occurrence: more in detail, the monitoring system is confirmed as the most used risk assessment methods (46%), followed by forecasts (18%), scenario analysis (8%) and sensitivity analysis (4%), which appears to be in accordance with studies reporting the need for knowledge development in order to sustain the decision making process (Batsakidis and Tsigkas, 2022).

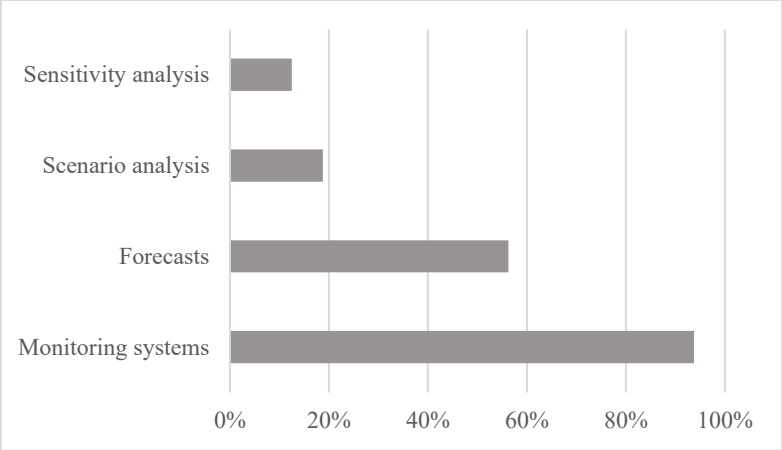

Figure 7 – Subsample's risk assessment methods.

Surprisingly, only one firm report that its monitoring system supports the estimation of potential negative impacts of climate change on financial performance and position, also allowing to distinguish between short- and long-term effects.

Regarding risk management measures, 8 respondents report to have integrated climate change risk management in their risk management system, if any, and only 12.5% of them has identified a corporate function in charge of climate risk management, as 7.5% of the surveyed companies have assigned this role to the sole proprietor or a board member, and two of them to an agronomist.

Consistently, 40% of the total sample have so far reacted to climate-related threats by adopting temporary measures, vs. 32.5% having permanently modified some aspects of their business activity: regardless of this, firms' responses are mostly adaptive and do not differ significantly, as they mainly consist of investments in new irrigation, water storage and barn cooling systems, and drought and heat stress resistant cultivation techniques and varieties. In addition, 56% of the sampled companies have opted for risk transfer through insurance coverage: Particularly, while 64% refers to general climatic negative events, some respondents specify that the insurance contract is related to hail (36%) or to draught and floods (18%), with 7 companies not indicating insurance typology. Last, it should be noticed that, on the whole, companies do not plan to seek external experts' support.

As a whole, results appear to confirm evidence provided by studies on organizations' response to emerging risk, highlighting that companies tend to adopt wait and see and adaptation strategies due to both their lack of knowledge and the high degree of uncertainty that affects forecasting ability, that in turn may hamper proactive strategic planning (Pyke & Tang, 2010).

5. Discussion and conclusions

Our findings show that while Italian companies in the upstream livestock supply chain appear to be aware of climatic risks in the short-term, they tend to perceive related future threats as impending to a lesser extent, consistently with previous findings. Indeed, responses provided by sampled firms reveal their knowledge of negative consequences potentially arising from changes in the natural environment, this being furthered by earlier experiences of unfavorable climate impacts, such as draught and floods occurred during summer 2021. In this regard, differently from evidence emerged in prior studies (Manning et al. 2015), respondents declare to be more concerned about physical risks threatening their production processes than about regulatory requirements on greenhouse gas emissions, probably due to the strong interaction between climate-related issues and human and natural systems characterizing the industry (Godde et al., 2021), together with the intense interconnections linking firms operating at the different stages of the supply chain. Accordingly, effects on crops and livestock growth and quality have been identified as the most severe climatic consequences at both the upstream and downstream levels of the supply chain, where lower attention seems to be paid to infrastructural damages that may be caused by extreme weather events.

Despite this, a smaller number of companies appear to acknowledge potential future developments of climate-related risks, thus confirming previous findings on the perception of climatic threats as distant in time and not urgent (Godde et al., 2021). In addition, this circumstance shows consistency with existing evidence on the complexity underlying emerging risks appraisal, due to their high levels of uncertainty and to the poor predictive capabilities of firms when they lack adequate experience and knowledge (Aven, 2016), as further testified by the sample's limited awareness of both EU and national climate change regulations.

Focusing on the sample's measures enacted to cope with climatic current and future challenges, no systematic adoption of climate change risk assessment and management systems emerges. Overall, few respondents have started to collect information on climate-related threats recurring to different external sources, and have implemented some assessment method, mainly a monitoring one. Nevertheless, only one company has adopted a forecasting system estimating climate-related outcomes on financial position and performance and allowing to identify short- and long-term effects. Additionally, few respondents report to have designated an internal function devoted to climatic changes management, while none of them has reported to rely on an *ad hoc* management system. Indeed, as shown by extant literature, sample's actions and measures undertaken or planned to face climate-related risks refer for the most part to reactive and adaptive strategies aiming at reducing, avoiding and/or transferring negative climatic effects (Merna and Al-Thani, 2008), enabling firms to promptly adjust their business activities to climate challenges as they emerge, with enduring changes mainly introduced in irrigation and cooling systems. In this perspective, an unexpected insight arises when considering that no reference is made to external consultants' involvement.

Such results can be explained by not only firms' tendency to underestimate emerging risks and deep uncertainties (Sejian, 2015), but also the averagely small size of Italian agricultural and livestock firms:

indeed, as declared by some interviewees, the expensiveness of investments needed to deal with climatic threats may hinder companies' ability to adequately prepare for future, unknown exposures.

Overall, our exploratory study provides several theoretical contributions and practical implications. From a theoretical standpoint, we support prior literature on emerging risks and supply chain risk management. First, the unfamiliarity and the lack of background knowledge on climate-related challenges poses questions on organizational capability to foresee and react to potential climatic threats, calling for dynamic responses that gradually incorporate past experiences to better respond to consequences of changes in the natural environment (Batsakidis and Tsigkas, 2022). Indeed, the observed cautionary, reactive and adaptive approaches can be interpreted in light of the sampled companies' low experience as they appear to be in early stages of risk learning, in which lessons learned about risk nature and consequences, along with response strategies effectiveness need to be stored and processed (Aven, 2016), since this "may lead to construction of more realistic risk models and more informed guesses about the future", because before and after analysis can help understanding "risk impacts and identify the reasons of success and failure" (Dikmen et al., 2008, p. 43).

Second, interconnections between firms in the livestock supply chain may foster risk identification, assessment and management criticality, as climate change risks magnitude and unpredictability may be exacerbated by the strong links that tie upstream and downstream entities together, thus hampering their ability to identify risk drivers and causal relationships, making threats opaquer and more unexpected (Batsakidis and Tsigkas, 2022), once again eliciting adaptive approaches (Parker & Ameen, 2018).

Last, the peculiar characteristics of the Italian livestock supply chain confirm prior study findings on industry- and entity-specific determinants of climate-related risks responses: on the one hand, it is argued that smaller firms are less likely to implement structured risk management systems (Brustbauer, 2016); on the other hand, the industry characteristics may allow price transmission to downstream firms and customers when shocks occur (Cattivelli & Antonioli, 2023; Carraro & Stefani, 2011).

Focusing on managerial implications, livestock firms' businesses are likely to be increasingly influenced by climate-related challenges. To address them, companies need to acquire adequate knowledge about climate change and its potential effects, to increase management's perception of climatic shifts potential effects (Sejia, 2015) and consequently both manage physical risks and reduce the impact of production processes on greenhouse gas emissions: indeed, while mitigation and adaptation strategies can appropriately serve this purpose, shifting from a reactive to a proactive approach could lead to most effective responses to disruptive events. Given the average small size of Italian livestock firms, turning to professional consultants could be a more efficient way to develop culture of specific risk and actions to minimize climatic negative effects, together with the adoption of supply chain level responses and the reliance on agricultural and livestock consortia.

From a policy-making perspective, climate-related measures should consider Italian agricultural and livestock firms characteristics in setting incentives to foster the adoption of appropriate risk management systems, also introducing financial support to promote investments in production systems innovation and

energy efficiency. Similarly, trade associations may play a crucial coordinating role in environmental effectiveness, by providing firms with regulatory and technical knowledge, collecting supply chain performance data, and participating in agreements negotiation (Bailey & Rupp, 2006).

Our study suffers from some limitations that at the same time suggest avenues for future research. First, our sample only covers the upstream stage of the livestock supply chain, while it would be interesting to investigate climate change risk assessment and management of downstream companies, such as distributors and retailers. Second, we focus on a small, Italian sample: as responses to climate-related threats are found to depend on industry-specific characteristics, more in-depth results could be reached by extending the research to other countries, with different livestock industry characteristics. Furthermore, additional insight may be provided by conducting customized interviews.

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PAPER III – The effects of climate change in the Italian agri-food sector: sample analysis of companies in the Calabria region in citrus and oil production

Abstract

As is well known, considerable changes are taking place in our planet's climate, caused by the increased concentration of carbon dioxide and other climate-altering gases in the atmosphere. This is reflected in increasing temperatures and the frequency of precipitation. Although many economic sectors are affected by this phenomenon, agriculture is certainly the sector most sensitive to climate change, which affects crop production and yields. For this reason, climate change is seen as a challenge that companies in the agri-food sector must face. The aim of the present work is to analyse the impact of climate change on the productivity of agri-food companies in Italy at a regional level. In particular, a regression analysis was carried out to estimate the impact of rising temperatures on citrus fruit and olive oil production in the Calabria region, which is considered one of the Italian regions most exposed to the effects of climate due to its geographical position in the center of the Mediterranean basin. The paper is divided into four paragraphs: i) introduction, ii) analysis of the effects of climate change in Italy and, in particular, in the Calabria region, iii) sample description and regression analysis, iv) conclusions.

Keywords: Climate change effects, agricultural sector, mitigation and adaptation strategy, business performance.

1. Introduction

Climate change is a topic of growing interest that has involved governments, institutions and universities in recent years. Since the industrial revolution, emissions of carbon dioxide (CO_2) and other climate-altering gases into the atmosphere have caused a slow but steady rise in temperature.

Scientific evidence shows that if large-scale reductions in greenhouse gas emissions are not implemented in the coming years, the increase in the earth's average surface temperature will exceed 2 degrees Celsius, causing extreme climate events such as strong heat waves, longer hot seasons, and shorter cold seasons (Alpino M., Citino L., De Blasio G., Zeni F., 2022).

The effects of global warming also include changes in humidity levels, wind strength, precipitation frequency and intensity as well as melting glaciers, rising sea levels and coastal erosion.

Among the economic sectors affected by climate change, the agri-food sector is certainly the most affected.

However, climate change has been shown in the literature to have both positive and negative effects on agriculture.

Indeed, in northern European countries, the increase in average seasonal temperature has favored the development of new crops, increased their yield and extended the area of arable land. At the same time, in southern European countries, climate change has had negative effects on agriculture, reducing crop yields and making crops more vulnerable to the effects of climate (Olesen and Bindi, 2002; Ewert et al., 2005; Iglesias et al., 2012).

Van Passel, Massetti and Mendelsohn, (2016) showed that farms in Europe are particularly sensitive to climate change.

In particular, southern European countries, including Spain, Portugal, Italy, Greece and southern France, are expected to be most affected by climate change.

This was recently confirmed by the second report (2022) published by the Euro-Mediterranean Centre on Climate Change (CMCC), which stated that the Mediterranean area will experience an average temperature increase of 20 per cent higher than the global one.

The Mediterranean basin is situated in a transition zone influenced by both the arid climate of northern Africa and the temperate, rainy air masses from central Europe (Giorgi, Lionello 2008).

Numerous studies conducted on a regional scale in the Mediterranean area (Brunetti et al., 2012, Deitch et al. 2017; Cloiero et al. 2019) have noted the relationship between total annual rainfall and seasonal trends, demonstrating a reduction in rainfall in the autumn and winter seasons and an increase in rainfall in spring and summer.

As a consequence of the variation in rainfall, Sirangelo et al., (2015) found a significant increase in drought periods.

Polade et al. (2017) showed that an increase in dry days is often associated with an increase in rainfall intensity and the frequency of extreme weather phenomena such as landslides and floods (Llasat et al. 2010, Gariano & Guzzetti 2016).

In this scenario, the Mediterranean basin is the area of greatest interest for observing the risks associated with climate change and, in particular, the region of Calabria, located in the center of the Mediterranean basin and characterised by a high heterogeneity of climate and topographical features from north to south, can be considered an interesting study area for the impacts of climate change.

More generally, it is expected that in Italy in the period 2020 - 2050 there will be an average temperature increase of + 2 degrees Celsius compared to the period 1981 - 2010, as well as a significant decrease in precipitation in the southern areas, accompanied by an increase in their intensity (CMCC Report, 2022).

According to Auci and Vignani (2014), climate change is an inefficiency factor for companies in the Italian agri-food sector, which is characterised by small to medium-sized enterprises with a low capacity to adapt to new climate challenges.

This work aims to assess the impact of climate change and, in particular, of the increase in temperature, associated with a change in rainfall, on farm yields in the Calabria region.

The work considers a sample of enterprises in the citrus fruit and olive-oil production sector.

1.1. Policies to combat and adapt to the effects of climate change

In recent decades, researchers have investigated how agricultural systems cope with and adapt to climate variability (Salpina D., Pagliacci F., 2022). This has led to the development of strategies for coping with and adapting to climate change.

In particular, the path of development of counter and adaptation strategies began in 1992, during the Rio Conference on Environment and Development, then with the United Nations Framework Convention on Climate Change (UNFCCC), culminating in the Kyoto Protocol (1997) and the more recent Paris Agreement of 2015.

Throughout this long *process* of study, observation and knowledge of the phenomenon, governments and institutions have realised that the causes of climate change, and of global warming in particular, cannot be traced solely to the emission of climate-altering gases into the atmosphere, but rather to a combination of causes including population growth, economic development, available resources and technology (IPCC, 1996).

Today, the academic community and the political world have become aware that in order to successfully reduce the risks of climate change, it is necessary to create a synergy between counteracting actions (also called mitigation) and adaptation.

Adaptation is defined in the literature as the "*process of adapting*" to the current or expected effects of climate change in order to moderate or avoid associated risks or create new opportunities (IPCC, 2014).

According to Ensor et al. (2019), there is a substantial difference between "adaptation" and "mitigation" in relation to climate change. While adaptation actions aim to reduce the risk, exposure and vulnerability of agricultural systems to climate alterations, mitigation actions are intended to facilitate long-term transformation.

In other words, the former work on the cause of climate change, the latter deal with its consequences.

Although contrast and adaptation actions are closely interconnected, they act on different spatial scales.

Counteracting actions take place at the planetary level, i.e., on the global average atmospheric concentrations of climate-altering gases that cause the greenhouse effect (Pietta A., Bagliani M., Crescini D., 2022).

However, being able to be implemented globally requires action at the territorial or even local level through the implementation of adaptation actions.

The IPCC's fifth report, published in 2014, marked a turning point in the fight against climate change by identifying the six priority areas for action to combat climate change: energy, transport, construction, industry, settlements and infrastructure, and agriculture.

These six sectors represent the main areas of climate change action. Among them, the agri-food sector plays a primary role as it is of fundamental importance for human well-being.

Numerous studies have assessed the climate change sensitivity of different dimensions of agricultural activity in different geographical areas, as well as the economic impact of climate change effects on agribusiness yields (Adams et Al., 2014).

According to Ingram (2012), a further conceptual problem relates to the variety of adaptation means of agricultural sector enterprises to cope with climate change. They vary according to form (technological or behavioral means), scale of application (at farm or system level), governance (depending on whether farmers, consortia, region or state), time (reactive, competing or anticipatory), duration (short or long term) and intensity of the measure.

However, although in theory the necessary actions to counter the effects of climate change have been identified, in practice governance practices to support agribusinesses in the process of transition and adaptation to new climate-environmental scenarios have not yet been adopted.

2. The effects of climate change on the Italian agri-food sector

The main cause of global warming lies in the increased concentration of carbon dioxide (CO_2) in the atmosphere, which started in the 1970s with the industrial revolution.

Climate change is mainly reflected in the increase in average seasonal temperatures and the consequent occurrence of extreme weather events such as heavy floods, heat waves and floods.

In particular, Europe has seen a temperature increase of 1° C above the global average over the last century (Iglesias et al. 2012).

Initially, researchers focused on assessing the impact of climate change on economic activities and human health. However, in more recent years, there has been an increased focus on the agri-food sector, as this is the economic sector most exposed to climate change since climatic conditions regulate agricultural production, yield variability and the extent of cultivable areas.

Italy is heavly affected by climate change, which poses risks and inefficiencies for companies in the agri-food sector. This sector is characterised by small businesses that struggle to adapt to new climatic conditions, such as changes in temperature and extreme weather events.

However, national institutions have not yet taken action to improve the governance of the agricultural sector, providing companies with the means to efficiently deal with the risks associated with climate change.

Over the last 20 years, an increasing number of extreme weather events have occurred in Italy. Particularly in the south of the peninsula, drought periods have increased significantly, and water shortages have forced companies to abandon some local crops and turn to new ones that are more resistant to the heat of summer.

Italy has a historical agricultural vocation and is the second largest producer of "fruit and vegetables" in Europe, after Spain, with high quality and typical Mediterranean products officially recognised as PGI and PDO (Auci, Vignani, 2014).

However, while the increase in average temperatures in the spring-summer period, in the areas of southern latitudes, makes agricultural production extremely difficult due to too high temperatures and water scarcity, the increase in average temperatures in the spring-summer period, in the areas of northern latitudes, favors crop production by extending the yield period.

In this scenario, there is a clear need to develop new production techniques and new systems for monitoring and forecasting climate change, in order to be able to adapt agricultural production to the new climatic-environmental scenarios and, at the same time, to take advantage of new development opportunities.

The existing literature has extensively studied the effects of rising temperatures on agricultural production in different areas of the world (Elbakidze, 2006, Easterling et al. 1993; Chang 2002; Peiris et al. 1996; Brown and Rosenberg 1999, Craigon et al. 2002; Jones and Thornton 2003, Shrestha et al. 2013).

However, few studies focus on the analysis of the Italian territory which, due to its location and geographical extension, is strongly affected by the effects of climate change.

In fact, the Italian peninsula is located in the center of the Mediterranean area, i.e., in a transition zone between the arid climate of North Africa and the temperate and rainy climate of Central Europe, and is vulnerable to changes in climatic conditions. In particular, the Mediterranean climate is characterised by mild, rainy winters and hot, dry summers, climatic situations that favor soil development, land morphology and karst topography (Caloeiro et al., 2016).

This paper focuses on the analysis of climate change in the Calabria region, which, due to its location and geographical extension, is the Italian region most affected by climate change.

2.1. Climate surveys in Calabria in 2022 - 2023

The territory of the Calabria region has physical and climatic characteristics that are anomalous compared to the rest of southern Italy; the surface is predominantly mountainous and flat areas occupy less than 10% of the entire territory (the largest flat area is the Sibari plain on the Ionian Sea).

On the basis of its physical and climatic features, Calabria can be subdivided into three main bands:

- Ionian belt, characterised by an impulsive rainfall regime, where long dry periods are followed by short but intense rainfall (Versace et alii, 1989).

- Tyrrhenian belt, which has a humid climate with twice as many rainy periods as the Ionian belt, but with less intensity.
- central belt, which runs from the Crati river basin to the Mesima river basin, characterised by intermediate climatic and geological features compared to the previous ones.

The 2023 report on weather-climate trends published by ARPACAL (Agenzia Regionale Protezione Ambientale Calabria) recorded anomalies in precipitation and temperatures, compared to the 30-year period 1991-2020.

With reference to rainfall, the report provides data on seasonal cumulative rainfall. In particular, for winter the January-March quarter was considered, for spring the April-June period, for summer the months of July to September and for autumn the months of October to December.

These data were considered in relation to the average seasonal precipitation over the 30-year reference period 1991-2020, obtained by considering time series of at least 20 years.

For the winter months, the analysis reports a significant rainfall deficit compared to the average for the reference period, recording a negative rainfall anomaly over the entire region, which amounted to between 20 and 50 per cent of the seasonal average precipitation.

On the contrary, an increase in rainfall was recorded over the entire region in the spring period due, in particular, to the occurrence of persistent heavy rainfall in May. The data show an increase in rainfall of three to five times the seasonal average.

During the summer period, the report shows a negative trend over the entire territory, with the exception of the Sila massif where rainfall maintained average values.

Finally, a lower rainfall deficiency than in the other seasons was observed in the autumn period.

In order to assess temperature trends, the analysis conducted by ARPACAL considers the difference between the seasonal average temperature and the seasonal normal temperature (i.e., the average of the seasonal average temperatures calculated from the observation years 1991-2021).

In particular, an increase in the average temperature of 15% over the winter period was recorded; the map of anomalies for the spring period shows an average temperature below seasonal values over almost the entire region.

In contrast, average temperatures in the summer period are 2°C above the historically higher temperature values.

The same trend was also observed in the autumn period with an average temperature increase of 2°C across the region, making it the warmest autumn in the last thirty years.

The data therefore confirm a trend of rising temperatures associated with altered rainfall periods.

This is reflected in agricultural activities, which must therefore necessarily adapt to the new climate challenges.

3. Description of the statistical sample

The objective of this paper is to analyse the economic impact of climate change on Italian agriculture at regional level.

For the purposes of the research, the region of Calabria was observed, which, located in the center of the Mediterranean basin, is the Italian region most affected by climate influence.

In particular, the effect of climate change on citrus fruit and olive oil production, the two main agricultural sectors of the regional economy, was estimated.

These crops need favorable microclimatic conditions and may suffer from long dry periods and unseasonably high temperatures.

In particular, Calabria is the second largest Italian region in terms of citrus groves, accounting for 21% of the national total (Smea, 2023).

At the same time, olive growing is a strategic sector for the made in Calabria and occupies about 24% of the cultivated agricultural area, with more than 100 varieties of olives grown (Coldiretti, 2023).

However, according to Istat data on the value of production, in the last decade the weight of olive cultivation in the regional total has fallen from 31 to 26 per cent and that of citrus fruits from 32 to 18 per cent due to climatic events that have endangered the production of oil and citrus fruits (Istat, 2023).

For this reason, research evaluates the effects of climate change on the profitability of these two agricultural crops in terms of temperature and precipitation, which are considered the main components of climate (IPCC, 2007, Solomon et al., 2007).

For the purposes of monitoring climate events, the Calabria region is divided into eight significantly homogeneous territorial zones, according to the type of meteorological and hydrological events that have occurred and are expected and the related risks.

The eight zones, also known as "*cove*", divide the region into two belts, the Tyrrhenian, and the Ionian, which in turn are subdivided into a further four distinct geographical zones in the north, center and south.

Table 1.1. - Weather zones in the Calabria region

Cove	Slope	Cardinal point
Cove 1	Tyrrhenian	Northern
Cove 2	Tyrrhenian	Northern Center
Cove 3	Tyrrhenian	Southern Center
Cove 4	Tyrrhenian	Southern
Cove 5	Ionic	Northern
Cove 6	Ionic	Northern Center
Cove 7	Ionic	Southern Center
Cove 8	Ionic	Couthern

Source: Protezione civile regione Calabria - Direttiva Sistema di allerta-meteo regionale per il rischio meteo idrogeologico ed idraulico in Calabria, 2017.

The data on average temperatures and cumulative precipitation were collected by the Regional Agency for Environmental Protection of Calabria (ARPACAL) for the year 2021.

The profitability of the sample companies was estimated from the financial ROA and ROE indices extracted from the Aida database.

In the first step of the research, a dataset consisting of 189 farms was compiled, of which 83 for citrus and 106 for olive cultivation.

Table 1.2. summarises the spatial distribution of the farms in the sample for the citrus fruit sector.

Table 1.2. Territorial distribution of citrus fruit farms.

Provinces	Cities	Cove	Company
Catanzaro	Catanzaro	7	1
	Cropani	7	1
	Satriano	7	1
	Sellia Marina	7	1
Cosenza	Acre	5	2
	Belvedere Marittimo	1	2
	Cassano allo Ionio	5	9
	Corigliano Rossano	5	25
	Rende	2	1
	Rocca Imperiale	5	1
	Santa Maria del Cedro	1	1
	Saracena	1	1
	Scalea	1	1

	Terranova da Sibari	1	1
	Trebisacce	5	1
Reggio Calabria	Bianco	8	2
	Bova Marina	8	1
	Bovalino	8	1
	Brancaleone	8	2
	Campo Calabro	4	1
	Cittanova	4	2
	Condofuri	8	2
	Feroleto della Chiesa	4	1
	Gioia Tauro	4	2
	Locri	8	1
	Melicucco	4	4
	Oppidio Mamertina	4	1
	Polistena	4	1
	Reggio Calabria	4	8
	Rosarno	4	1
	Stilo	8	1
	Taurianova	4	1
	Varapodio	4	1
Vibo Valentia	Limbadi	3	1

As shown in the table, the sampled companies are distributed across 34 municipalities in the region, covering the provinces of Catanzaro, Cosenza, Reggio Calabria and Vibo Valentia.

Among the companies analyzed, 59% are located in the northern part of the region (provinces of Catanzaro and Cosenza), while 41% are situated in the southern part (provinces of Reggio Calabria and Vibo Valentia).

With regard to the distribution by climatic zone, the following emerges:

- Northern area: 16% of the companies are on the Tyrrhenian side and 84% on the Ionian side;
- Central area: 20% are located on the Tyrrhenian side and 80% on the Ionian side;
- Southern area: 70% of the companies are on the Tyrrhenian side and 30% on the Ionian side.

Approximately 30% of all companies are concentrated in Corigliano Rossano in the province of Cosenza.

These companies are located in the Sibari Plain, between the Ionian Sea, Sila and the Pollino massif, and is the largest plain in the region. Here, potassium-rich soil and a mild climate with moderate temperature variations create ideal microclimatic conditions for citrus fruit production, to the point that the local clementines have obtained PGI (Protected Geographical Indication) status.

Table 1.3. Territorial distribution of oil producing companies.

Provinces	Cities	Cove	Company
Catanzaro	Amaroni	7	1
	Belcastro	7	5
	Borgia	7	3
	Catanzaro	7	5
	Cortale	3	1
	Gizzeria	3	1
	Lamezia terme	3	3
	Maida	3	3
	Marcellinara	7	2
	Pianopoli	3	1
	Squillace	7	1
Cosenza	Amantea	2	1
	Belvedere Marittimo	1	1
	Bisignano	2	1
	Cariati	6	1
	Cassano allo Ionio	5	1
	Castrovillari	1	5
	Cleto	2	1
	Corigliano Rossano	5	1
	Cosenza	2	5
	Crosia	5	1
	Dipignano	2	1
	Firmo	1	1
	Mongrassano	1	1
	Montalto Uffugo	2	1
	Pietrapaola	6	1
	Rende	2	1
	Vaccarizzo Albanese	5	1
Crotone	Ciro	6	2
	Ciro Marina	6	3
	Cotronei	6	1
	Crotone	6	6
	Crucoli	6	2
	Mesoraca	7	1
	Petilia Policastro	6	8
	Roccabernarda	6	2
	Strongoli	6	3
Reggio Calabria	Bova	8	1
	Bovalino	8	1
	Catanzaro	7	1
	Cinquefrondi	4	1
	Cittanova	4	1

	Delianuova	4	1
	Gioia Tauro	4	3
	Locri	8	1
	Melito di Porto Salvo	8	1
	Oppidio Mamertina	4	4
	Reggio Calabria	4	2
	Roccella Ionica	8	1
	Rosarno	4	1
	Scido	4	1
	Siderno	8	2
	Terranova Sappo Minulio	4	1
	Varapodio	4	1
Vibo Valentia	Francica	3	1
	Vibo Valentia	3	2

The data in Table 2.3. reveal that holdings in the olive growing sector are located in 56 towns in the region divided among the five provinces.

The holdings are evenly distributed throughout the territory, with a higher concentration on the southern Tyrrhenian slope (cove 4) and the central-northern Ionian slope (cove 6), accounting for 40% of the sample total.

Olive cultivation extends from the coastal plains to the hilly and mountainous areas where the Mediterranean climate, characterised by warm, sunny summers and not too harsh winters, favor the cultivation of olive trees.

From this first extraction, it was necessary to reduce the sample to 93 observations, of which 44 were for the citrus sector and 49 for the olive sector, as ARPACAL's meteorological stations only offered up-to-date measurements for 24 cities (2021 data).

A statistical analysis was conducted on the basis of this dataset.

3.1. Regression analysis

Based on the above considerations, a statistical analysis was carried out using a simple linear regression model, the equation for which can be described as follows:

$$Y = {}_i\beta_0 + \beta_1 X + {}_i\varepsilon$$

The dependent variable Y tests the profitability of the sample companies and is represented in the model by the ROA and ROE indices.

The univariate analysis revealed that the ROA and ROE in the distribution take on negative values and, for this reason, it was not possible to perform a logarithmic transformation in order to normalise the distribution.

However, remember that at the statistical level, economic and financial variables are not normal.

The non-normality in the distribution is also evident from the box-plot, which shows a high presence of outliers, and from the histogram, which shows an obvious leptokurtosis, i.e. the pronounced sharpening of the curve, typical of financial variables.

Figure 1.1 Box plot and ROA histogram

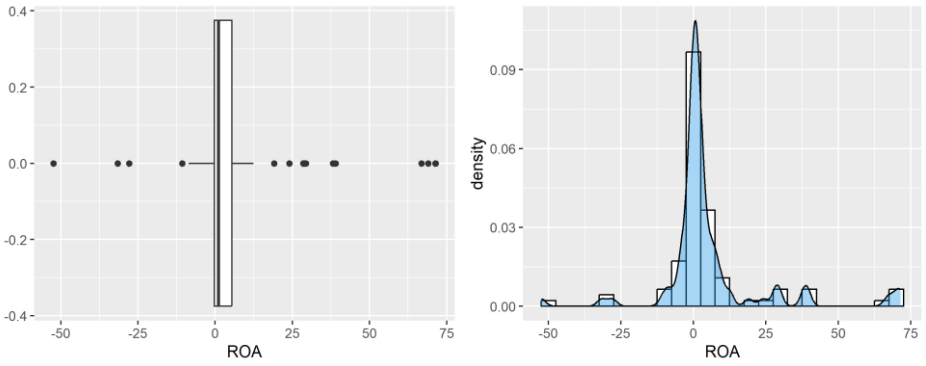
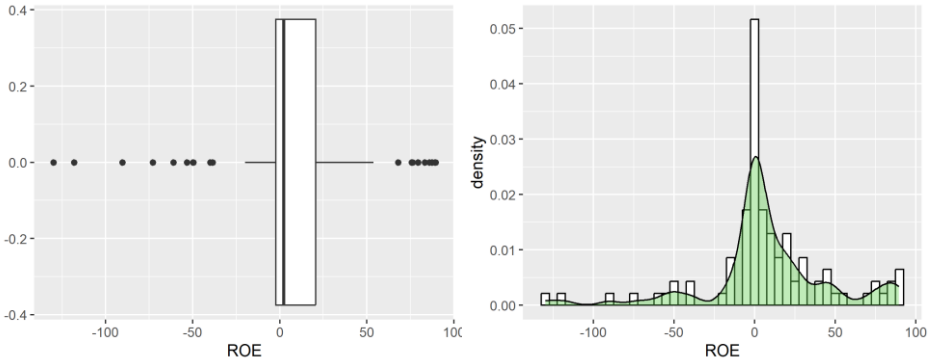


Figure 1.1 Box plot and ROE histogram

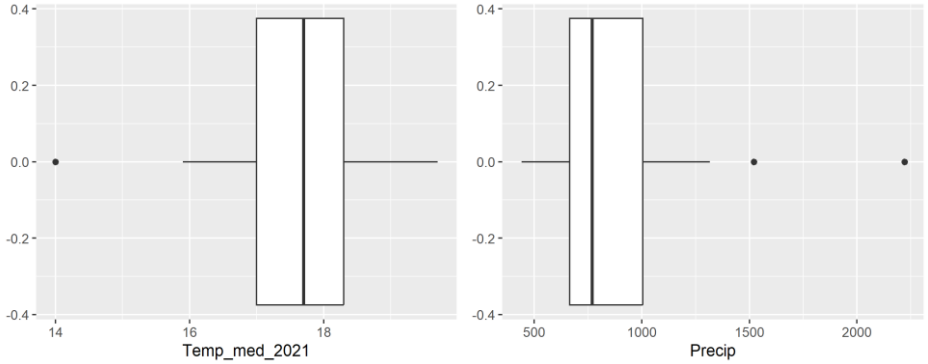


The dependent variables X, descriptive of the model, refer to the sector (citrus and oil), the province, average temperatures and cumulative rainfall.

In particular, the temperature and rainfall surveys report 2021 data, available for all observations in the sample.

The univariate analysis showed only one outlier for temperature and two outliers for precipitation.

Box plot temperature and precipitation (2021).



Subsequently, descriptive statistics were carried out on the quantitative variables of the model since the ROA and ROE indices showed outliers. On a statistical level, in fact, the presence of outliers and the non-normality of the distribution make it necessary to calculate the median index, the latter being more robust than the average.

The coefficient of variation was also estimated, which is synonymous with excessive variability when it takes on values greater than one hundred.

Both indices confirmed the variability of the distribution for both ROA and ROE.

Table 3.1. summarises the results of the analysis.

Table 3.1. Descriptive statistics of ROA and ROE.

	ROA	ROE
Min.	-52.410	-130-000
Lst Qu.	-0.290	-2.170
Median.	1.070	2.200
Mean.	5.407	7.304
3rd. Qu.	5.440	20.690
Max.	71.420	89.550

However, it was not possible to reduce the variability as both indices assumed negative values in the distribution making a logarithmic transformation inapplicable.

At the same time, it was decided not to exclude negative values from the sample in order not to lose representativeness of the phenomenon described as the sample consisted of only 93 observations.

This was further confirmed by the Shapiro-Wilk test, suitable for small samples, which revealed a p-value of 1.455e-06 leading us to reject the null hypothesis H0 of normality for ROE.

Shapiro's test also confirmed the non-normality of the distribution for precipitation (p-value = 2.961e-05) and temperatures (p-value = 1.309 e-08).

Therefore, the non-normality of the quantitative variables necessitated the use of non-parametric tests.

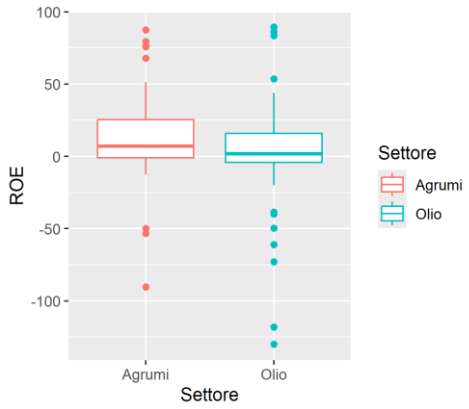
Using bivariate analysis, the relationship between the variables was captured.

Given the non-normality of ROE, the non-parametric Wilcoxon test was performed to assess the relationship between this index and the industry.

The test has as null hypothesis H_0 that the median ROE of companies in the citrus sector is equivalent to that of companies in the oil sector, and as an alternative hypothesis H_1 that the medians are different.

The test found that there is no relationship between ROE and sector, i.e. the medians are statistically equivalent (p-value=0.2468).

Image 4. Box plot of the non-parametric Wilcoxon test.



The same result was reached when considering the relationship of ROE with the provinces and of ROE with the area.

This led to the exclusion of these variables from the regression equation.

In order to estimate the correlation between the quantitative variables, the Spearman method was used, which lends itself to the analysis of non-normal variables.

The test shows a strong negative correlation between temperature and precipitation. This reminds us that an increase in temperature results in a significant reduction in precipitation.

Following this analysis, the regression model took ROE as the independent variable Y and average temperatures and cumulative precipitation as dependent variables X.

The regression results are significant and are shown in Table 3.2.

Table 3.2. Results of the regression analysis.

	Estimate Std.	Std. Error.	T value	Pr (> |t|)
Intercept	211.15560	88.02959	2.339	0.0185*
Temp_med_2021	-9.41177	4.53255	-2.076	0.0407*
Precip.	-0.04511	0.01758	-2.566	0.0120*

Signif. Codes: 0 *** 0.001 ** 0.01* 01 1

Adjustes R- Squared: 0.05733

The value of the R adjusted reflects the non-normality of ROE.

The intercept takes a value of 211 and average temperatures have a negative impact, more precisely, for every additional degree centigrade, ROE is reduced by -9.41. We can therefore state that the increase in temperature negatively affects ROE.

Likewise, for each unit change in precipitation, ROE decreases by -0.05.

Finally, the analysis of the residuals tested the goodness of the model. It is recalled that the model's residuals must meet the following tests i) null mean, ii) homoschedasticity, iii) uncorrelation, iv) multicollinearity and v) normality.

The t-test on the mean revealed a p-value = 1, so the hypothesis is fulfilled.

Homoschedasticity was demonstrated by the Breusch-Pagan test in which the null hypothesis H_0 is homoschedasticity of the residuals and the alternative hypothesis H_1 is heteroschedasticity.

The test reports a p-value greater than 0.05 (p-value = 0.1278) so we accept the null hypothesis of homoschedasticity.

The Durbin-Watson test tested correlation by assuming as null hypothesis H_0 the absence of correlation against the alternative hypothesis H_1 of correlation.

The test verifies a p-value greater than 0.05 (p-value = 0.323) and allows us to accept the null hypothesis of uncorrelation.

The test also verifies the absence of multicollinearity by showing a VIF value of less than 5.

Finally, the Shapiro-Wilk test tested the normality of the model. The p-value is less than 0.05 (p-value = 0.003618) and does not allow us to accept the null hypothesis of normality.

However, this does not affect the goodness of the regression model since it is closely linked to the non-normality of the ROE which, assuming negative values in the distribution, could not be transformed.

4. Conclusions

In the last decade, climate change, due to the concentration of greenhouse gases in the atmosphere, has caused an increase in temperatures and the consequent alteration of rainfall periods.

These two phenomena have affected the yield of agricultural production that is particularly susceptible to climate change.

However, numerous studies have shown that climate change has had positive consequences for agriculture in northern European countries where higher temperatures and reduced rainfall have created favorable climatic conditions for agricultural yields.

On the contrary, climate change has had negative consequences in the countries of the Mediterranean basin with a consequent economic loss for companies in the sector.

This was also demonstrated by the analysis of the sample subject of this paper.

Indeed, regression analysis showed that the increase in temperatures, closely correlated with the reduction in rainy periods, had a negative impact on the profitability of companies.

However, although the sample can be considered representative, it is believed that the work can contribute to the development of future research.

In fact, more up-to-date meteorological observations and surveys could provide a better representation of the observed phenomenon.

Furthermore, based on the above, it is believed that further regulatory action is needed to provide businesses in the sector with the necessary knowledge and tools to meet the challenges posed by climate change.

It can be said that the companies in the Calabria region are representative of the entire Italian agricultural sector, which is mostly characterised by small and poorly structured companies.

These companies would need clear guidelines and adequate economic resources in order to efficiently address the transition process to sustainable agriculture that can take into account climate change while ensuring food security.

This would allow the Italian agri-food sector to maintain its leadership in the economy by guaranteeing the excellence of its products.

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