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Five paradoxes navigated by incumbent private sector firms moving towards climate-oriented innovation in food systems

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The role of large private sector firms in rerouting our food systems towards sustainability through climate-oriented innovation is highly contested. The contestation has resulted in a portrayal in academic literature of these incumbents as either the key driver of sustainability transitions or as fundamentally contradictory to addressing climate change in food systems. Controversies and tensions can reinforce stalemates, which hamper progress towards climate-oriented innovation. This study explores the utility of a paradox lens which shifts the research gaze to the emergence of unavoidable and persistent tensions in encounters of distinct logics and lines of action, and opens space to examine how these encounters can nevertheless be used productively and creatively in overcoming stalemates. Based on reflexive practice and interviews with professionals from seven purposefully selected incumbent private sector firms in the agri-food sector, we identify five paradoxes: the paradox of direction—between mitigation and adaptation; the paradox of justification—between exploration and exploitation; the paradox of internal alignment—between mainstreaming and specialization; the paradox of external alignment—between collaboration and competition; and the paradox of evidence—between accountability and learning. Our analysis of how agri-food firms navigate paradoxes focuses on considerations, tensions, and decisions in organizing climate-oriented innovation. In our discussion, we examine whether and how paradoxical thinking enables civil society practitioners to accelerate climate-oriented innovation in food systems through interactions and collaborations with the private sector. We conclude that a paradox lens affords researchers, practitioners, and policymakers to move beyond the binary view on the role of incumbents' climate-oriented innovation, and instead provides strategic insights for engaging incumbents and their inherent contradictions in transforming our food systems under a changing climate.

KEYWORDS

paradoxical thinking, food transformation, innovation, innovation studies, incumbents, climate change, agri-food firms, private sector

1 Introduction

Despite considerable efforts, our food systems persist on an unsustainable trajectory, amplifying the call for transformation in both international policy (United Nations, 2021) and research (Willett et al., 2019). Innovation is being positioned as a critical element to achieve the needed change. It is a core element of global policy conversations, exemplified by the

centrality of innovation in both the agenda of the United Nations Food System Summit (von Braun et al., 2023), as well as the latest UNFCCC COP28 Presidency (2023). However, while food systems contribute around a third of greenhouse gas emissions (Crippa et al., 2021), only 5% of total global R&D investments are targeted at food and agriculture (Pardey et al., 2016). At the same time, we know that significant investments are required: USD 10.5 billion in additional investment in agriculture research and innovation per year is estimated to be needed in the Global South to reduce hunger by 5% and reach emission targets in line with the Paris Agreement (Rosegrant et al., 2022). This highlights the need to urgently scale up innovation and its funding to ensure food systems can re-orient to a more sustainable trajectory.

Currently, investments in food and agriculture innovations are increasingly coming from the private sector (Fuglie, 2016). In food processing, private companies are already the dominant funder of research and development (R&D) (Fuglie and Toole, 2014), and agricultural R&D, which traditionally relied on more public investment, is on the same trajectory in several regions and sectors (Fuglie, 2016; Pardey et al., 2016). Most of these investments come from large firms that are well-established in the current food and agriculture market: Fuglie (2016) found that the 23 firms with the largest agricultural R&D spending (in 2014) accounted for 70% of total global agricultural R&D investments by the private sector. Yet, while large firms have disproportional R&D capacity, these are not necessarily steered towards new breakthroughs, as R&D resources are also employed to defend the status quo, focusing on further establishing existing products and patents (Béné, 2022). Given the influence and role of private sector firms in food and agriculture innovation, it is important to understand if and how their innovation can support climate action in food systems.

That the private sector, including farmers, small- and medium enterprises, and large international corporations, is an essential actor group in any discussion on food systems transformation is discernible, as markets and value chains are key organizing structures in our food systems. In a context of dwindling public investments, private sector innovation is expected to become even more important to address the climate challenges in our food systems. Premise of this line of thinking is that the magnitude of private sector R&D resources and investments, as well as the scale of their operations, can be critical to accelerating innovation and sustainability (Barrett et al., 2022; Gonera et al., 2023; Magnusson and Werner, 2023; Moberg et al., 2021; Turnheim and Sovacool, 2020). Yet, the contribution of large firms to realizing climate-oriented innovation in food systems is subject to controversies. The coupling of a need for significant innovation investments to address climate change and the strong involvement of the private sector in R&D projects, investments, and policy have raised concerns among practitioners, academia, and civil society. This is especially so because larger and established firms, by definition, have a stake in the status quo, which presents an obvious contradiction to the transformation of that exact same system. In addition, where traditionally public agricultural research might have provided some insurance that innovation investments addressed public goods, private investments in food and agriculture innovation do not inherently prioritize those (Clapp, 2021; Conti et al., 2021; Turnheim and Geels, 2019). Hence, assessing the role and contribution of private sector innovation in addressing climate-related challenges is a controversial subject, which has drawn special attention to the long-established and dominant—or incumbent—private sector actors and how their innovation (investments) may help or hinder efforts of systems transformation.

A result of the controversy on the role of innovation by these incumbent firms in the food systems transformation agenda is a binary framing in academic literature that portrays them as either the key driver of sustainability transitions or as fundamentally contradictory to addressing climate change in food systems. This divided debate gives rise to strong opinions and scrutiny in either direction, and reduces incumbent firms to black boxes in which the practicalities and nuances of their strategies for innovation in a climate change context are obscured. This ultimately reinforces stalemates, in which practitioners have little space to explore the practicalities and opportunities for working with incumbents. In this paper, we aim to contribute to the unpacking of the black box of incumbent firms' climate-oriented innovation efforts. We do this by employing a paradox lens for analyzing logics and considerations for a climate orientation in the innovation efforts by incumbent firms. Our research question is: What paradoxes and strategies to deal with them exist in the organization of climate-oriented innovation by incumbent firms in food systems?

In this research we focus on the specific group of organizational private sector actors with strong material and discursive power to shape prices, technologies and policies (Clapp, 2022), which we conceptualize as incumbents. In the broader literature on sustainability transitions, Turnheim and Sovacool (2020) have called for pluralizing our understanding of incumbents, and thereby exploring the subtleties of incumbents' contribution or undermining of sustainability transitions. Several recent studies have taken up this challenge focusing on different sectors, (Altunay and Bergek, 2023; Bohnsack et al., 2020; Kungl, 2024; Vormedal et al., 2023) with a few discussing incumbents in various parts of our food systems specifically (Bulah et al., 2023; Friedrich et al., 2023; Gonera et al., 2023). Following Kungl's (2024) call for more specific definitions in studies of incumbents in sustainability transitions, we take incumbent firms to be private sector organizational actors that have a significant size and market share in their respective sub-sectors and are long-established and strongly embedded in the market.

We aim to advance the debate on incumbents by using and evaluating whether and how a paradox perspective makes it possible to move beyond the gridlocked discussion on the role of incumbent firms' innovation in food systems transformation. By definition, paradoxes are persistent over time and cannot be resolved (Smith and Lewis, 2011). As such, it demands a *both/and* mentality instead of an *either/or* framing (Carmine and De Marchi, 2023; Lewis, 2000). Paradox theory has been applied to explore different organizational concerns (Lewis, 2000; Papachroni et al., 2015), including innovation (Andriopoulos and Lewis, 2009; Erdogan et al., 2020; March, 1991). More recently it has been used in specific domains, including corporate sustainability (Carmine and De Marchi, 2023; Hahn et al., 2018), agricultural research ecosystems and projects (Labarthe et al., 2021; Turner et al., 2017), and development evaluation (Faling et al., 2023). These studies provide examples of how a paradox lens can capture the nuances of competing logics and how paradoxical tensions can be used creatively and made productive. Hence, it is from this point of departure that we seek to explore the utility of a paradox lens to unpack how incumbents align their actions with climate-oriented innovation.

We use the term climate-oriented innovation to capture innovation that has an explicit climate angle. While several terms exist to describe

innovation that addresses sustainability issues, including 'green innovation' (Karimi Takalo et al., 2021), 'sustainable innovation' (Boons et al., 2013; Cillo et al., 2019), 'responsible innovation' (Lubberink et al., 2017) and 'sustainability-oriented innovation' (Adams et al., 2016; Gonera et al., 2023), climate-orientated innovation is used here to indicate a more precise focus on innovations that address climate change issues (as opposed to a wider set of sustainability considerations).

For our research, we build on interviews with private sector professionals working on innovation and climate in seven large incumbent agri-food firms. In addition, we build on the experiences of the first and second author who work at an organization active at the intersection of science, policy, and practice, providing reflexive practitioner contributions drawn from our observations and engagements with incumbent firms and industry bodies. We identify five paradoxes in climate-oriented innovation by incumbents and highlight the added value of a paradox lens for understanding these tensions and possible approaches for navigating them.

The following section will first provide an overview of the two opposing perspectives in the academic debate around incumbents' ability to enhance climate action in food systems through their innovation efforts. Subsequently, a paradox lens is introduced as a third and alternative perspective to understanding firms' climate-oriented innovation efforts. After a discussion of the materials and methods, the paper then dives into the five identified paradoxes. The discussion focuses on the contributions of a paradox lens to both scholarly and practitioner agendas. In doing so, it also touches on the implications for the broader discussion in this Special Issue on readying research and innovation systems for the 21st century.

2 Perspectives on incumbents' role in climate action for a food systems transformation

There are two main perspectives in the academic literature on the role of incumbents and how their innovation efforts can support rerouting our food systems to a sustainable trajectory, specifically in the context of climate change. On the one hand, there is the call for more interaction with the private sector, which particularly champions incumbents for their investment and scaling capacity. On the other hand, there have been strong critiques of the rising involvement of incumbents in the food systems transformation agenda and promotion of technological innovation. This tug-of-war leads to a contested field for practitioners, researchers, and policymakers working on this topic. The two perspectives are highlighted in the sections below. We then explore the value of a third perspective—a paradox lens—as a way out of this stalemate.

2.1 An optimistic perspective on incumbents' climate-oriented innovation efforts

The argument for more collaboration with the private sector, and particularly incumbents, on the rerouting of our food systems is two-fold. First, with public funding slowing down in recent years, different forms of collaboration with the private sector are increasingly pursued as a way to "crowd in" private sector investments (Fuglie and Toole, 2014). Within the private sector, incumbent firms have the largest innovation capacity in terms of investments, infrastructure, and knowledge (Fuglie, 2016; Fuglie et al., 2011), and are therefore interesting candidates for such collaboration. Partnerships, financial measures, and policy incentives are proposed as strategies to effectively access those resources for innovation targeted at sustainable development, including climate goals (Barrett et al., 2022). Secondly, private sector firms, and especially incumbents, might be more effective in disseminating and scaling innovations, since they operate on large (world) markets and have direct relationships with both producers and consumers (Lee et al., 2021; Schut et al., 2020; Smyth et al., 2021; Woltering et al., 2019). In addition, a growing body of literature explores how incumbents help accelerate climate-related transitions, either in their own market, but also regularly in adjacent markets (see for example Mylan et al., 2019; Turnheim and Geels, 2019). As such, engaging existing firms in innovation efforts has been high on the policy agenda, for example in the lead-up to the UN Food Systems Summit in 2021 (von Braun et al., 2023). Hence, under this perspective, leveraging the resources and reach of incumbents is an essential argument for policy, research, and practitioners to work on supporting and promoting innovation by these firms as a way to close the innovation gap towards more sustainable food systems.

2.2 A critical perspective on incumbents' climate-oriented innovation efforts

Others look critically at the increased collaboration with and reliance on incumbent firms for innovation investment, and their involvement in agenda and standard-setting activities, both on a national and international scale. Literature exploring the political economy of food systems, for example, highlights incumbents' influence to build narratives and shape policies through both direct and indirect power as well as the risks of depoliticizing decisions by framing them as technological problems (Anderson and Maughan, 2021; Canfield et al., 2021a; Clapp, 2022; Conti et al., 2021; De Schutter, 2017; Hackfort, 2023; Leach et al., 2020). The further corporate concentration in many food systems sectors has been highlighted as an amplifying factor of incumbents' power (Clapp, 2021, 2022). As a result, incumbents would be able to present their own technological innovations as solutions, further coupling the food systems to high-tech and industrial farming and entrenching their dominance. In addition, several studies have identified incumbents' strategies to undermine innovations and policies targeted at aligning (food) systems to a more sustainable trajectory (see for example Béné, 2022; Clapp, 2021, 2022; De Schutter, 2017; Smink et al., 2015). This skepticism is underscored by a long history of specific efforts by agriculture and food industries, such as those of tobacco (Savell et al., 2014), alcohol (McCambridge et al., 2018) and ultra-processed food (Clapp and Scrinis, 2017; Moodie et al., 2021; Scott, 2018), to protect profit over public health and environment. These studies present valid risks of engaging powerful private sector actors like incumbents in development and international policy on climate action, and there have been several calls to actively reduce corporate involvement in this kind of policy spaces (Canfield et al., 2021a; Canfield et al., 2021b; Montenegro de Wit and Iles, 2021). Hence, following this perspective, policy, research, and practitioners should be very cautious of interacting and legitimizing incumbents through collaboration on innovation.

2.3 A perspective to navigate contradictions: a paradox lens

These two perspectives present a gridlock for those working with incumbents to accelerate climate action and innovation in food systems. There are valid concerns about engaging large and powerful incumbents, while they are also positioned as critical players for scaling climate-oriented innovations through their direct links to both primary producers and consumers. Yet, this framing of the discussion on the intentions and desirability of climate-oriented innovation led by incumbents flattens the conversation to a binary stalemate.

One important cause of this stalemate is that in both perspectives incumbent actors tend to be lumped together as a homogenous group of either innovation heroes who will drive progress or relentless retardants who are undermining change. As a result, incumbent firms are reduced to black boxes labelled either supportive or undermining of a transformation of our food systems, without any deep exploration of the forces, tensions or nuances *within* firms. There is an emerging body of literature that seeks to diversify the understanding of incumbents' role in hindering and accelerating sustainability transitions (Gonera et al., 2023; Kungl, 2024; Magnusson and Werner, 2023; Turnheim and Sovacool, 2020). These studies illustrate that incumbents can simultaneously display tactics for defending the status quo and accelerating change through their innovation efforts, highlighting that the complexity of incumbents' behavior is relevant to how policy, research, and practitioners can engage with them to accelerate climate action. This requires a way to understand the reality of climate-oriented innovation by incumbent firms, including their (internal) contradictions and diversity. It is here that we believe a paradox lens can make a valuable analytical contribution to unpacking the black box of incumbent firms.

Paradox theory covers a broad research field that is concerned with understanding paradoxes and the "tensions, defenses, and their management" (Lewis, 2000) by individual and organizational actors. The paradox lens has a strong embeddedness in management and organizational literature, with most applications focusing on organization-level analysis (see for example, Andriopoulos and Lewis, 2010; Erdogan et al., 2020; Hahn et al., 2018). As such, it offers heuristic devices for understanding contradictions and dualities *within* firms.

Smith and Lewis (2011) have defined a paradox as follows: A paradox arises out of contradictory yet interrelated elements (dualities) that exist simultaneously and persist over time; such elements "seem logical when considered in isolation, but irrational, inconsistent, and absurd when juxtaposed." Hence, each paradox consists of two logics that are interrelated, contradictory, and persistent (Lewis, 2000; Smith and Lewis, 2011). Figure 1 provides a visualization of a paradoxical tension, where two opposing logics (illustrated by the red and blue pins) create a continuous pull in opposing directions. Yet, the two logics remain interconnected, like being tied together by an elastic band. As a result, the more one follows the directions of one logic, the stronger the pull from the opposing logic becomes, causing a persistent tension. As such, a paradox differs from a dilemma in that options in a dilemma are not connected by this imaginary elastic band; a dilemma is an enforced choice between two options which may or may not be related. The interrelated nature of two logics in a paradox, on the other hand, presents an *unresolvable* tension in which a pursuit of one direction only strengthens the relevance of the other.

The explicit appreciation of interrelated logics and tensions that paradox theory offers provides a useful lens to contribute to the unpacking of the black-boxed incumbent firms and their climate-oriented innovation efforts. It avoids a generalized conclusion of the potential of these incumbents to contribute to climate action through their innovation efforts, but instead enables more precise insights into the tensions that exist and incumbents' strategies to deal with those. In turn, it enables the acknowledgment of the double-edged role of incumbents as described in the two perspectives above, without presenting it as an either/or dilemma. This not only enables a more nuanced understanding of incumbents' role but also supports practitioners and policy makers working with or along incumbents by offering space for the nuances and ambiguities that are inherent to climate-oriented innovation by incumbent firms. As such, it provides an avenue to a more productive conversation on ways of interacting with incumbents, instead of a polarized discourse in which they are scrutinized either way.

Some recent studies in the field of agricultural innovation have been influenced by paradox theory (see for example, Labarthe et al., 2021; Turner et al., 2017), although these studies primarily focus on the exploration-exploitation tension (March, 1991) in innovation and do not look at incumbents' innovation efforts. Recently, a paradox lens has also been applied in other related contexts, including development evaluation (Faling et al., 2023) and corporate sustainability (Carmine and De Marchi, 2023; Hahn et al., 2018). These studies provide examples of how a paradox lens can contribute to opening the conversation around contradictions that are presented as binary dilemmas. Hence, with this paper, we seek to explore the value of the paradox lens for analyzing incumbents' climate-oriented innovation efforts, while simultaneously contributing to this emerging variety of applications.

3 Materials and methods

We combined interviews with individuals working at a selection of incumbent agri-food firms with observations and experiences gathered through engagement with incumbent firms in the climate and food policy space. The first and second authors are both practitioners working at the intersection of science, policy, and practice. In this capacity, they have established a boundary

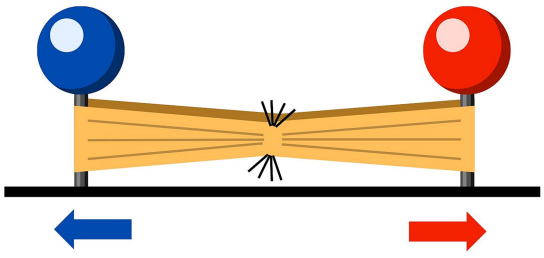

FIGURE 1
A visualization of a paradoxical tension: Two pins representing opposing logics are connected through an elastic band while they continuously pull in opposing directions. Due to the elastic band, following one direction will only further strengthen the pull from the opposing logic.

organization (Guston, 2001) in which they work closely with incumbent private sector actors, policymakers, and researchers. We were therefore able to draw on these experiences to identify areas of tension based on prior interactions with these firms, for example in project development and policy engagement. It also provided us with a strong network and background knowledge to identify firms and research directions. To complement these practitioner perspectives, the third author is an academic with an interest in the open-ended nature of innovation process and the associated micro-politics of unfolding innovation in a private sector setting, which provided a critical and balanced perspective for evaluating and verifying our insights. Thereby we were able to combine practitioner and academic perspectives in this paper.

This paper is the result of a reflexive process in which experiences and reflections from our professional activities informed the research scope and analysis, while the research itself informs our strategy for interacting with incumbent firms. The lead author kept a research diary to record insights from professional interactions and engagements, which informed the discussion among the authors as well as with experts and practitioners and supported the analysis of the interview data. The discussion highlights how the research results continue to inform our practice and offers new and reflexive perspectives on engaging incumbent firms to pursue climate goals through innovation.

The firms in this study were selected because they met our definition of incumbents: having a significant size and market share in their respective sub-sectors and being long-established and strongly embedded in their markets. In addition, the firms were also selected because some of the authors had established relations with people at these firms, which helped us in arranging their participation. Table 1 provides an anonymized overview of the firms that were included. The competition dynamics, as well as the average size and innovation investments, differ per sub-sector, which means that the selected firms include a somewhat diverse range in terms of sizes.

In total, we spoke with 11 innovation, sustainability, and corporate affairs experts from the 7 large agri-food firms listed in Table 1. The interviews were semi-structured, conducted online, and voice-recorded, after which they were transcribed. One interview could not be recorded due to technical issues; detailed interview notes were made for this interview. Each interview started with a general exploration of the firms' scope and activities, followed by questions about how climate change is perceived in relation to the firm, and if and how climate action is embedded into the firm's activities and strategy. Subsequently, questions focused on understanding the firms' innovation strategy and processes. After this separate examination of the topics of climate and innovation, the interview focused on exploring how these connect within the firm, as well as bottlenecks, tensions and success stories. This general structure helped ensure we covered the relevant topics, while still providing flexibility to unpack interesting avenues that developed over the course of an interview. The data was anonymized for the publication of this article to ensure interview confidentiality. In preparation for the interviews and to complement the interviewees' insights, we consulted publicly available documents and websites, including firm webpages, annual financial reports, and ESG or sustainability reporting for information on the firms' climate commitments and innovation strategy.

The data analysis was an iterative process that combined the initial insights from the interviews, the paradox lens, and the reflections from several engagements we had as practitioners. The first step in the analysis focused on exploring the data through open coding to identify areas of tension between firms' innovation and climate efforts, as well as arguments and logics that the interviewees provided to explain their handling of these tensions. This inductive analysis led to the identification of common areas of tension described in the interview. We then combined this with insights from paradox literature on characteristics of paradoxes and distinct logics, as well as established paradoxes in relation to innovation, to develop a first list of potential paradoxes. We further refined this list and our understanding of the different logics through several rounds of interactions with other experts and practitioners, as well through a second, more filtered, analysis of the interviews. This filtered analysis was based on the initial categorization of paradoxes and helped ensure the identified paradoxes were distinct, covered the tensions discussed in the interviews and supported the refinement of the different logics underlying them.

TABLE 1 Anonymized overview of interviewed firms.

	Type of firm	Area of business	Number of employees	Sales revenue as available in the latest reporting period (2022/2023 or 2023)*
A	Private sector firm (listed)	Farming input products, including chemicals and technologies	> 80,000	> 25 billion EUR (of which around ½ is food and agriculture-related sales)
B	Private sector firm (listed)	Farming input products, including chemicals and technologies	> 80,000	> 25 billion EUR (of which around ¼ is food and agriculture-related sales)
C	Private sector firm (listed)	Food & beverage ingredients trader	< 20,000	10–25 billion EUR
D (2 interviewees)	Private sector firm (family-owned)	Seed company	< 20,000	< 5 billion EUR
E (2 interviewees)	Private sector firm (family-owned)	Consumer food producer	< 20,000	< 5 billion EUR
F (2 interviewees)	Private sector firm (listed)	Ingredients for food and farming products	20,000–80,000	10–25 billion EUR (of which around ¾ is food and agriculture-related sales)
G (2 interviewees)	Private sector firm (not listed)	Farming input products, including chemicals and technologies	20,000-80,000	> 25 billion EUR

*For firms with branches outside the food and agriculture sectors, we indicate the portion of their sales revenue derived from food and agriculture-related sales.

In terms of interactions with experts and practitioners, we conducted 6 background interviews with experts who work with the private sector; these included industry bodies working on innovation and climate change, and experts working on this topic in government, research, or investment. Initial findings of the analysis were also shared with a broader group of private sector experts through formal and informal engagements by the lead author. These included roundtable discussions and conversations at international gatherings related to climate and food, including the UNFCCC 28th Conference of Parties (COP28) and the World Economic Forum in Davos in 2024. Notes were taken on the insights from these interactions, and these were particularly helpful in the formulation and refinement of distinct logics. As such, the iterations between the interview analysis and interactions with practitioners provided additional insights and served as verification and contextualization of the findings. This analysis using a paradox lens drew attention to both logics and explanations as well as areas of tension, which enabled the identification of five paradoxes that require navigation in the context of climate-oriented innovation by incumbents, which the following section sets out.

TABLE 2 Five paradoxes of climate-oriented innovation in food systems by incumbent firms.

Paradox	Central question	Competing logics
Direction	What climate change problems are innovation efforts directed towards?	Adaptation
		Mitigation
Justification	How to justify investments in climate-oriented innovation?	Exploration
		Exploitation
Internal alignment	How to organize climate-oriented innovation in the wider organization?	Mainstreaming
		Specialization
External alignment	How to interact and align with other firms?	Competition
		Collaboration
Evidence	How to generate evidence for climate-oriented innovation?	Measurement for accountability
		Measurement for learning

4 Results: five paradoxes in incumbents' climate-oriented innovation

The five paradoxes highlighted here illustrate tensions and competing demands in the wide range of decisions and choices made by incumbent firms while organizing their climate-oriented innovation efforts. We structured them in line with five activities of organizing an innovation process: (1) the direction towards which innovation efforts are oriented, (2) the justification for investing resources into pursuing innovation, (3) the internal alignment and organization of innovation within the firm, (4) the alignment with external parties, specifically other firms, and (5) the generation of evidence. Table 2 lists the identified paradoxes and their accompanying competing logics. These five cover the breadth of the steps in climate-oriented innovation in firms and cover central themes that arose throughout the interviews. While we present them in a listed format, the five paradoxes are not sequential *per se*; they are to be navigated simultaneously in the processes of climate-oriented innovation, interacting along the way. In addition, it is important to note that the logics we present also exist in other levels and domains, such as policy and research agendas—yet the below analysis focusses on how these paradoxes play out on the firm level. Each paradox is explored by examining the competing logics, illustrated by examples from the interviews, and subsequently highlighting tensions and strategies associated with navigating the two competing logics.

4.1 The paradox of direction

The first paradox we identify is related to the way innovation is directed to address climate change challenges. Here, we build on the distinction between climate change mitigation and adaptation. In the context of food systems, adaptation focuses on increasing resilience and securing the productivity of our food systems under the effects of climate change. Mitigation, on the other hand, is concerned with reducing the contribution of food systems to climate change. These two concepts represent two distinct logical points of departure (Tol, 2005), even if synergies are also achievable (Smith and Olesen, 2010). In the context of innovation, they present two logics for firms to direct their innovation efforts to specific problems presented by climate change.

A logic of mitigation centralizes firms' innovation efforts around reducing emissions as the main target of climate-oriented innovations. All interviewees highlighted mitigation and the reduction of emissions as central to their climate-oriented innovation efforts. As interviewee F1 explained: "*The mitigation, so that's the avoiding of emissions and supporting customers also to achieve their climate goals, is at the moment the key priority.*" Several interviewees also highlighted private sector firms and their innovation capacity as an important opportunity to reduce emissions: "*Corporations have these huge opportunities, you know, to drive the decarbonization of our planet, and we can act faster: we can definitely invest on a larger scale, and we can actually make the right connections across the value chain.*" *(G1)* These mitigation efforts might take the shape of reducing emissions by improving technologies to help farmers "*farm in a more efficient way, trying to use less resources*"*(G1)*, or supporting producers to improve their on-farm practices to reduce emissions from, for example, fertilizer (Firm C). Innovations with a mitigation orientation might also focus on developing entirely new products to replace high-emitting products or, as interviewee D1 explained, innovations in logistics and processes within the firm itself. All of these efforts have an explicit orientation to reducing the emissions of the firms' products and operations.

The logic of adaptation follows the opposite direction. Here, climate-oriented innovation is aimed at reducing the effects of climate change on the firms' products and operations. The consequences of climate change, including droughts, heat, floods, and changing climatic zones, will have a major influence on the markets of these firms. For example, interviewee D1 highlighted

that new pests and diseases are developing and spreading faster due to climate change, while harvest losses due to climate change could significantly threaten trading firms (such as Firm C). As such, an adaptation logic to climate-oriented innovation highlights the need for firms to anticipate a changing climate and innovate in response to that: "*Wherever the climate is changing, we need to breed for that.*"*(D1)* Opposed to the framing of mitigation as an opportunity for climate action, multiple interviewees framed adaptation challenges as risks for the firm. In Firm F, for example, the task force that deals with anticipating the consequences of climate change is part of the risk-management group. Interviewee C also highlighted the need for adaptation to help farmers improve their resilience to shocks: *"The whole problem with the climate change, and the climate shocks are more to do with resilience […] farmers are basically trying to struggle to survive for half a hectare, you know, and they just keep their heads above the water, and then you get a little movement—then you can go underwater*." As such, the logic of adaptation orients innovation more as a response to climate change as opposed to a way to halt it.

The directions implied by the two logics contradict on two fronts: the framing of climate change as a risk or opportunity, and the scale and type of innovations to be explored. Firstly, where adaptation-oriented innovation was described in the context of responding to risks ("*helping growers, you know, to cope with drought conditions, flooding conditions*"*(G1)*), mitigation-oriented innovation was described as an opportunity (*"There's a lot we can do to reduce CO2 emissions in agriculture a lot more than we can do than what we are currently doing, and there I'm really excited by some of that work that could be done in the next few years."(B)*). Secondly, orienting innovation to mitigation incentivizes a focus on innovations that can reduce emissions as much as possible. Here, innovations that can be applied to large farms and can easily be scaled are the low-hanging fruit for increasing the volume of emission reductions. In contrast, adaptation needs, especially in low- and middle-income countries, are much more relevant for the most vulnerable, small-scale farmers with less investment capacity, resulting in different needs: "*A lot of those innovations for smallholders, you know, aren't based on genetics and chemistry, they are based on equipment and digital tools or practices,* versus *actual inputs."(A)* As interviewee G1 said, for adaptation a focus should be "*having those technologies be affordable, you know, across the globe, not only for some kind of premium customers or some, is really if we want to, you know, cope with adaptation of climate change*." As such, the direction in which innovation is targeted influences the type of customer and application that is to be explored under the firms' climate-oriented innovation efforts.

While the two logics of adaptation and mitigation are contradictory, they are also interrelated as mitigation results affect adaptation needs and vice versa. All interviewees underscored the importance of both adaptation and mitigation: "*We need to be able, you know, as a society to also adapt to climate change and to live with the consequences of that while we are still trying, you know, to reduce emissions (G1).*" There are some instances in which a combination of the two logics is feasible because an innovation addresses their double need: an example of such a win-win innovation is drought-tolerant seeds that require fewer inputs (mitigation) and are more resilient in the face of droughts caused by a changing climate (adaptation). Limited resources and the contradictions described above, however, complicate bundling adaptation and mitigation wins and maintain the tension between them. One strategy to still address both climate orientations is to split them organizationally. We observed this in several firms: Firm F mainly incorporates adaptation in their risk team, Firm C has separate projects to address adaptation and resilience of their producers, while Firm D addresses adaptation in their innovation prioritization while the operational team addresses mitigation efforts.

4.2 The paradox of justification

The second paradox identified here relates to the justification for directing a firms' resources to innovation for climate action. Here, we build on a well-known paradox from the innovation studies literature: the exploration-exploitation paradox (Andriopoulos and Lewis, 2009, 2010; Gupta et al., 2006; March, 1991; Smith and Lewis, 2011). The exploration-exploitation paradox highlights the need for firms to simultaneously exploit their current capacities and markets while exploring new markets, products, and skills to survive in an ever-changing field of competition. Climate change presents a clear example of this dynamic: it threatens a firm's current markets and business models directly through increasing risks and shocks or indirectly through policies and regulations that are targeted to mitigate climate change. In this context, firms justify their investments in climate innovation through the two logics of exploitation and exploration.

The first logic approaches climate change as a challenge that brings additional costs, conditions, and risks under which the firm and its products need to survive: "*You have to adapt. It's a survival of the fittest - Business Edition.*"*(D2)* Following this logic, innovation investments are justified as improving or exploiting existing products and value chains to prepare them for a world under a changing climate. Interviewee D1, for example, explained: "*We have about 100 years of experience breeding for climate conditions*." As a result, they described themselves as well-positioned to identify traits that enable climate adaptation without having to significantly expand their capacities or adapt their business models. Other input firms explained that increasing the yield and efficiency of their products is a strategy for addressing climate concerns through their innovation pipeline. As one of the interviewees explained: *"Everything has some level of sustainability benefit because, at the end of the day, if we are producing more with the same inputs, that's better."(A)* Under this logic, investment in innovations is then justified as increasing efficiency and, therefore, improving the existing products and profit margin of the firm.

The second logic also departs from understanding climate change as a threat to current products and value chains but positions the exploration of new markets, products, and business models as a key focus of innovation for climate change. For several of the firms working directly with farmers, this exploration primarily focuses on new business models. For example, interviewee G1 explained that digital solutions are an increasingly important product for their firm. These new digital products are an alternative model to solely focusing on volumes of inputs, which are a significant contributor to emissions. Interviewee A highlighted that this is especially an important business model for targeting smallholder farmers who have fewer resources to

purchase large volumes of inputs but are highly vulnerable to climate shocks. Interviewee B also shared an example of an experiment with a business model where they collaborated with local farmers and other supply chain actors to include ecosystem services performed by farmers in the consumer price of a locally produced end product. Under this logic, a firm's investments in innovation can also be justified as exploring entirely new markets, either in geography or products. Interviewee C, for example, explained that the drastic effects of climate change might require them to explore entirely new geographies for sourcing their produce, while the interviewees of Firm F explained their investments into alternative protein innovation as supporting their sustainability targets. As such, this logic justifies investment in climate-oriented innovation as an opportunity to secure new market opportunities in the future: "*It means that you really need to fuel your R&D pipeline, you know, with the right criteria, the right thoughts on how the world would change in the next 10 years because the product that our R&D team is currently developing today will only reach the market in the next 10 years."(G1).*

These two parallel logics for justifying innovation investment into climate action present two important contradictions: one around the time horizon and one around the firm's relationship to the status quo. In terms of the time horizon on which the positive effects of the innovation are expected, exploitation secures shorter-term profitability while also addressing sustainability issues, whereas exploration requires risk-taking for capitalizing on evolving opportunities. Interviewees B and C, both at listed companies, highlighted the short-term horizons of shareholders as an important limitation in exploring new business models and markets since these innovation investments take longer to materialize. The interviewees of Firm E, a family-owned company, however, described that the family's priority of sustainability concerns is a key enabler for embedding climate and long-term concerns into their innovation strategy and investments. A second contradiction to these justification logics lies in how they portray the impact of these innovations on the relation of the firms to the status quo. The exploitation logic and its focus on improving existing products and business models tie the firms closer to current markets and their dynamics. As such, it steers towards incremental innovations. The exploration logic for innovation investments, on the other hand, implies a change in the firm's identity and role within the wider food systems, enabling more disruptive innovations.

While these contradictions exist, many of the interviewees relied on both logics when justifying a need to invest in climate-oriented innovation. As interviewee A explained, there are two arguments for pursuing this kind of innovation: one is addressing the gaps and needs of today, and secondly, innovation is required to identify "*what is over the horizon*" in terms of technology, products, and challenges. This highlights the interconnection of and persistent need for balance between the two logics, as exploration can lead to future exploitation, and exploitation enables investment in exploration. To accommodate both of these logics, nearly all firms have a dual approach to climate-oriented innovation, which is pursued both in their internal innovation pipelines and in external configurations. Climate-oriented innovation that is pursued through internal innovation pipelines tends to build on existing capacities "*we have the infrastructure, we have the expertise, we have the bandwidth," (A)* and is therefore closely tied to the justification of improving yield, productivity, efficiency, and profit of existing products in current markets. On the other hand, external innovation that addresses climate issues, for example, in ventures and collaborations, is justified as helping to "*figure out the evolving landscape*" *(E)* and the firm's role therein. The following two paradoxes explore these internal and external innovation efforts.

4.3 The paradox of internal alignment

The third paradox we highlight is related to how a climate orientation is aligned within the organization. All interviews highlighted that in recent years, climate change has become increasingly important in their organizational strategy. However, we observed different logics for approaching the translation from strategy to the organizational reality of the firm's innovation efforts: one of mainstreaming climate into existing innovation processes and one of dedicating specialized organizational units to climate-oriented innovation.

Under the first logic of mainstreaming, a climate orientation is organized by including climate experts, indicators, and considerations in all innovation efforts. As interviewee F2 explained: "*From the very beginning of an opportunity all the way to the end, you have a sustainability expert on the team, identifying opportunities, raising flags, and so on.*" The interviewees from Firms A, B, and G also explicitly mentioned that they include sustainability experts or indicators throughout their internal innovation pipeline. The reasoning for this is twofold. Firstly, mainstreaming helps to identify climate benefits and risks across all innovations. For example, Firm G identified an unexpected but particularly climate-positive variety in their pipeline due to mainstreamed climate indicators in their stage gate process. At the same time, mainstreaming also helps to inform or steer innovation investments. As interviewee A explained: "*Whilst it may potentially be the best thing that's ever been invented […] if it does not contribute to our sustainability objectives, then we would have the power to perhaps maybe redirect that R&D somewhere else.*" Secondly, strong indicators on climate have become especially relevant in the face of new regulations, like the EU Corporate Sustainability Reporting Directive (CSRD), the disclosure standards of the International Sustainability Standards Board (ISSB), and recently adopted mandatory climate-related corporate disclosures by the US Securities and Exchange Commission (SEC). Mainstreaming climate considerations assists in meeting reporting requirements and identifying potential avenues to reduce emissions.

Following the second logic, climate-oriented innovation is pursued in specialized innovation efforts. Several of the firms highlighted that climate-oriented innovation often requires expertise that they do not have internally, and centralizing these efforts in a specialized team or unit can reduce the costs of the needed capacity building. In addition, separating more ambitious but risky innovation efforts from the general innovation pipeline can also protect these from the need for immediate results. In Firm A, for example, an ambitious innovation was pursued through a separate venture, and the interviewee explained: "*If we had done the work internally, you are always butting up against the 17,000 other things we could do.*" Furthermore, most firms had institutionalized sustainability roles or teams, but Firm E was the only firm with an institutionalized and dedicated fund for climate-oriented R&D. This fund is dedicated to

deploying emission-reducing innovations that might not have a stand-alone business case. The interviewees explained this as an essential step to pursuing climate-oriented innovations that would otherwise get stuck in the general innovation pipeline because of more extended payback periods or underdeveloped markets. They described this as ensuring transformative ideas are not "*sucked into the status quo*." This highlights that the way firms align climate-oriented innovations internally is an important paradox that influences the type of innovations and the conditions under which firms pursue them.

These two opposing logics present apparent organizational and capacity tensions. Where mainstreaming a climate orientation into existing innovation efforts requires the alignment of climate indicators and experts to existing processes, specialization involves establishing new processes that need to be aligned to the broader firm structure. Similarly, mainstreaming demands distributed capacity development on climate-related issues throughout the innovation units of the firm. This is different for specialized units where the capacity development needs are highly concentrated. As a result, they present different risks for effective climate-oriented innovation. By mainstreaming climate-oriented innovation, climate concerns become one of the many things on a checklist of investment considerations. Aside from profitability, interviewees also mentioned nutrition, health, infrastructure, education, nature, and biodiversity as considerations that may align but may also compete with climate-oriented innovation. As such, there is a risk of diluting the climate concerns in the broader list of priorities, something that Gonera et al. (2023) have also observed. On the other hand, specialized climate-oriented innovation creates the risk of misaligning with the firm's core business. As interviewee E2 explained, when venture innovations, including those related to climate, are too separate from the main business model, those involved in the core business, or shareholders, will raise concerns about the value of those investments.

Hence, the two logics present an interrelated tension, as the more a firm specializes their climate-oriented innovation efforts, the stronger the potential gain of mainstreaming becomes. However, firms attempt to leverage this paradox effectively by blending strategies for mainstreaming and specialization. For example, by embedding a climate orientation into general innovation processes, innovations with an important climate contribution can be identified. However, many of the interviewees raised the issue that oftentimes, the business case for specifically climate-oriented innovations is not defensible for further investment. This can be caused by an underdeveloped market, increased costs for producers or consumers, or regulatory difficulties. By ensuring interaction with dedicated climate experts and, more importantly, climate-specific innovation funds, these innovations still have an opportunity for further development and piloting. In Firm E, for example, the existence of a climate orientation at the dedicated climate innovation fund, the venture arm, and the core innovation pipeline provides multiple opportunities to pursue innovations with strong climate potential.

4.4 The paradox of external alignment

Next, to the internal alignment, how incumbents align with other external firms presents a fourth paradox. Here, there are two logics to engaging with others in their climate-oriented innovation: collaboration or competition.

The first logic of active collaboration builds on the idea that firms need to address similar climate questions, and that collaboration might help to pool resources, knowledge, and risks. Establishing collaboration requires coordination costs; as interviewee B stated: "*The biggest amount of time is actually agreeing and jointly understanding what the concept is, what is it that we really want to jointly achieve?*" However, once established, collaborative innovation interactions with external actors were frequently mentioned as a solution to a firm's lack of expertise, resources, and scale. Firm C, for example, works with universities and fellow firms in specific supply chains on how to organize their innovation pipeline in line with the concept of regenerative agriculture. Interviewee C explains the reasoning for this interaction as follows: "*When we really want to move the needle on sustainability, you have to take more of these landscape approaches, that's quite complicated, and it's quite expensive. And that of course, you know, you need this kind of diverse partnerships, you know, where everybody chips in resources, and everybody has a role to play.*" In addition, collaboration with partners can also be strategic when there is no clear way to profitability yet: "*While there are some exciting ideas or opportunities from an intellectual or scientific perspective, sometimes the business case does not allow it yet to be pushed forward. One of the opportunities we can take is partnering externally.*" *(F2)* In other situations, firms may work with others in their value chain to implement emission-reducing innovations to lower their own scope 3 emissions as well as those from their downstream customers. As such, the logic of collaboration presents an argument for sharing cost, knowledge, and risks associated with climate-oriented innovation.

However, the second logic frames climate-oriented innovation as an area of competition with other firms. With increased legislation and traceability requirements, particularly on emission reporting, those firms that are most successful in implementing climate-oriented innovations could potentially benefit, either by avoiding legal action or by charging a "green premium" to customers. Several of the interviewees highlighted that this would require either a willingness of customers to pay a premium for climate benefits, or a policy push to incentivize investments in climate-oriented innovations, neither of which is always widely established. However, as climate regulations increase and demand develops, investing in internal capacity to realize emission reductions and ensure traceability, might provide a competitive advantage. As interviewee C said: *"As [Firm C] we are probably better placed than some of our competitors, right, to deliver the services. So, we are like, well let the private sector compete for this*." Furthermore, interviewee C described that the element of competition is an important reason for not sharing all insights into their climate strategies and innovation in the public domain: *"If we throw it out in the public domain, then our competitors would be, you know, be able to copy paste.*" Instead, they communicate fragments of their approach to ensure that they still communicate their climate efforts to customers without competitors copying their efforts.

These two logics provide an interrelated and continuous tension, as it concerns the relationship that firms develop through their interactions with other firms. Where collaboration requires the development of trust and open sharing of lessons, the logic of competition requires the opposite. Another contradiction lies in the implications for innovation investments. Through collaboration, firms

can crowd in expertise from other firms but also share the costs of external expertise from, for example, universities and public research institutions. This reduces the investment costs but limits the competitive advantage the firm can develop from it. Approaching climate-oriented innovation as a way to develop a competitive advantage, on the other hand, steers towards the development of internal capacities and the associated investments. Interviewee A explains this tension as follows when describing a new innovation opportunity: "*We could do this, but we'd need to hire 30 people who know how to do this thing that we do not have today. Or we can do this through a partnership where you actually got some more flexibility.*" As such, the two logics contradict on the level of information sharing with competitors, but also in the focus of capacity development and investments.

Still, all firms pursued both collaborative and competitive climate-oriented innovation. Two important elements in navigating the tension between the two are to what extent there is a clear business model and how close the pursued innovation lies to their current skill set. By pursuing innovations in collaboration, legal as well as operational boundaries enable firms to "ring fence" the risk associated with it. This is especially relevant for early-stage innovation, or for innovations that might help address regulatory requirements, for example on emission measurement, but will not directly lead to an increase in profitability.

4.5 The paradox of evidence

The last paradox lies in how evidence is generated for the climate impacts of innovations as they are being developed and deployed by firms. Here we build on the duality between accountability and learning, which is well-established in evaluation literature (Faling et al., 2023; Reinertsen et al., 2022). Under recent legislation, firms are increasingly required to report and verify their climate impacts and claims. Therefore, data and measurements have a role to play in terms of holding firms accountable, and firms are developing innovations to support this climate-related reporting. On the other hand, the development of climate-oriented innovations also requires experimentation and exploration, in which research and measurement are important learning and development tools. These two different logics of evidence of climate-oriented innovations' impact present the fifth and final paradox that we highlight.

The first logic associated with this paradox is the use of research and measurement as evidence for accountability and reporting purposes. Under this logic, data and measurements are essential tools to verify the climate impacts of innovations and their deployment. The interviews highlighted two important reasons for following this logic. The first is that verified climate claims provide opportunities to capture a green premium, or at least, improve firms' climate track record. Strong measurements and indicators are important to do so: *"If I cannot quantify it, and I cannot claim it, then I cannot get money for it."(C)* In line with this, several interviewees also highlighted the need for research and measurement to counter accusations of greenwashing. A second reason for a focus on this use of data and measurement for accountability is the policy push created by recently adopted legislation, which requires reporting, particularly on emissions. Hence, under this logic, there is a strong need for standardized measurements and indicators that are comparable between firms. Most of the interviewees shared that they are actively working with sector organizations to develop these indicators, to ensure a level playing field. As interviewee B states: "*We have to have some indicators that everyone can agree on that can be easily measured, and can be, more importantly, easily verified, because we cannot use this as greenwashing.*" Similarly, interviewee F1, for example, said: "*We hire third-party experts to deliver a third-party report that has more amplitude than our internal views*." As a result, under this logic, standardization and collaboration with academia or external research institutes is seen to bring legitimacy or credibility to the evidence.

However, interviewees also highlighted a second logic that underscores the need to use evidence as a tool for learning, especially in contexts where climate-oriented innovations are in the early stages of development. Here, the focus lies less on standardizing indicators and more on developing evidence to understand climate-related challenges and test potential climate-oriented innovations in specific contexts. One example is the testing of new products in different closed ecosystems for several years. Firm B is pursuing this approach to identify interactions of complementary innovations that promote climate-oriented outcomes. However, these trials are limited in number and cannot be applied to all products, as "*it'd become far too expensive*." Hence, they use the evidence generated in those trials for learning and developing ideas that then feed back into their broader innovation pipelines. Other interviewees, like those from Firms C, E, and F highlighted how they work with external experts to bring in expertise on topics that they, as a firm, might not traditionally have, for example on smallholder farmer resilience in the face of climate change, or measuring climate and environmental outcomes. In these instances, the evidence helps to identify insights and lessons to further develop their climate-oriented innovations.

This logic of generating evidence to learn about climate-oriented innovations contrasts with the logic of using measurements for reporting and accountability purposes. The first contrast lies in the level of granularity that they pursue. The accountability logic strongly steers to a focus on standardized and generic indicators. These tend to focus on mitigation efforts, as "*at least we can measure carbon*"*(B)*, whereas adaptation is much more context-specific as the suitable innovations depend on other elements like "*infrastructure, education, health, nutrition, and diversification.*"*(C)* A second contrast lies in how the generated evidence is used. Where a logic of accountability uses evidence to externally communicate the impact of their climate-oriented innovation efforts, a logic of learning uses it to develop lessons that inform the further improvement of innovations internally and among partners.

As such, the two logics steer towards different strategies and priorities for generating evidence. However, these two logics are also an opportunity to develop an iterative cycle, since they are interconnected: accountability can highlight specific learning needs, while evidence from learning can inform efforts to meet accountability standards. For example, interviewee F1 shared that reflecting on standardized life cycle assessment results together with peers and NGOs helped them develop a sense of what paths to explore internally. Similarly, interviewee C shared that attempts to standardize emissions measurements in their value chain turned out to be quite inaccurate as they did not account for many of the on-farm practices of their producers. As such, attempts to standardize measurements for accountability purposes also developed evidence

that helped to identify new potential areas for climate-oriented innovations. Hence, while each logic presents a different way to use measurement and research as evidence for climate-oriented innovation, the interaction between the two logics can also help further their development.

5 Discussion and conclusion

This article presents five paradoxes of climate-oriented innovation by incumbents in food systems: the paradox of direction—between mitigation and adaptation; the paradox of justification—between exploration and exploitation; the paradox of internal alignment—between mainstreaming and specialization; the paradox of external alignment—between collaboration and competition; and the paradox of evidence—between accountability and learning. In contrast to a divided debate, a paradox lens helps understand the practical nuances and productive strategies of incumbent firms for dealing with contradictions associated with climate-oriented innovations. The tensions that underlie these are not either/or choices that can be made: it is not a question of adaptation *or* mitigation, exploration *or* exploitation, mainstreaming *or* specialization, collaboration *or* competition, learning *or* accountability. Instead, each of these logics holds value and exists simultaneously, resulting in paradoxes. As such, these paradoxes offer an alternative lens to the binary discussion of incumbents in which they are presented as black boxes that either undermine or champion food systems transformation.

Our paradox approach provides a starting point for practitioners and policymakers seeking to strengthen a climate orientation in incumbents' innovation efforts while being aware of the contradictions that it entails. As reflexive practitioners, we have found that this lens is helpful in shaping our interactions with incumbent firms in two important ways. Firstly, the five paradoxes provide a heuristic device to understand the (dominant) logics and tensions within firms. The identification of these logics does not provide a categorization of "productive" or "unproductive" climate-oriented strategies *per se*; in fact, incumbents can demonstrate both undermining and sincere behavior under each of the 10 logics. Instead, a paradox lens provides conceptual tools to understand how firms approach climate-oriented innovation, and identify alternative entry points and allies within incumbent companies. For example, firms that might be reluctant to invest in climate-oriented innovation from an exploitation logic could be invited to explore a productive model for working together under a frame of exploration and supported by other (public) stakeholders in the innovation system.

Secondly, a paradox lens and an understanding of strategies to deal with them also point practitioners to assess if there is space in their engagements with firms to approach these tensions productively or not. In our own engagement with incumbents, we have found that the acknowledgment of tensions by incumbents, as well as the presence or absence of strategies for dealing with them, provides an important marker to assess the openness of incumbents to reflect and act on their firm's ability to address climate change challenges. As such, a paradox lens enables the nuance needed for shaping our engagements with incumbents and their innovation. Instead of simply labeling incumbent innovation as either undermining or promoting more sustainable food systems under climate change, our analysis supports the opening of the black box of firms and provides strategic insights for practitioners engaging with them.

Furthermore, by employing a paradox lens, this paper brings a new social science perspective to the discussion of incumbents' role in the innovation systems of the 21st century, contributing to the much-needed diversity in this field (Hellin et al., 2024). Our analysis echoes Turnheim and Sovacool's (2020) call for a more pluralistic understanding of incumbents. The paradoxes expose how incumbent firms continuously navigate the tensions intrinsic to organizing climate-oriented innovation. An instructive example is how a strong specialization on climate-oriented innovation in a centralized organizational unit can complicate an adaptation orientation, as that requires more context-specific knowledge and experimentation. Our study presents examples of incumbent strategies to simultaneously build on two competing logics, such as organizationally splitting adaptation and mitigation efforts, or changing the interaction strategies with other firms and stakeholders as climate-oriented innovations come closer to market. Approaching these dualities in unfolding innovation processes as paradoxes draws attention to these two logics that are in tension, as well as their interrelatedness, and thereby underscores the need for analytical and practical approaches to understand the navigation of persistent competing demands.

On a methodological and conceptual level, the paradox lens opens a future research agenda building on insights from the literature on *ambidexterity*, which examines the ability to address and manage two contradicting logics in a duality, such as a paradox (Andriopoulos and Lewis, 2009). This literature identifies three broad strategies for achieving ambidexterity in an organization: (i) architecturally, i.e., splitting the two logics structurally, for example in different teams, (ii) contextually, i.e., strengthening the ability of teams and individuals to judge the balance as the context requires and, (iii) temporally, i.e., balancing two logics and their implied focus by cycling through them in sequences over time (Andriopoulos and Lewis, 2009, 2010; Papachroni et al., 2015). These ambidexterity strategies enable firms to deal with the competing logics of a paradox, given that there is no route to truly resolving them. Table 3 identifies a set of plausible ambidexterity strategies rooted in the identified paradoxes, which future research can elaborate, typify, and contextualize. This would not only support the identification of more strategies for incumbent firms to deal with paradoxes but also the conditions for their effectiveness.

We conclude that a paradox lens is a valuable contribution to both the academic literature discussing incumbents' role in food systems transformation and the work of practitioners interacting with these incumbents. The paradoxes we identify in this paper deepen our understanding of the ways in which incumbents navigate tensions intrinsic to organizing climate-oriented innovation. It provides practitioners seeking to accelerate climate-oriented innovation in food systems, including ourselves, with heuristic tools to shape their interaction and collaboration with the private sector. Furthermore, a paradox lens pushes future research to move beyond labeling incumbents and their actions as (un)productive or seeking solutions to dualities. Instead, by taking tensions to be persistent, it opens up a research direction that identifies practical strategies for navigating contradictory demands that are inherent to the transformation of our food systems.

TABLE 3 Examples of ambidexterity strategies.

Ambidexterity type	Strategies to pursue ambidexterity	Example from the interviewed firms
Architecturally	Exploring adaptation and mitigation in two separate organizational units (*paradox of direction*)	Firm F mostly addresses adaptation concerns through its risk unit, and mitigation by its innovation and operational teams
	Dedicated venture and other investment funds with a climate-related mandate (*paradox of internal alignment*), or a specific focus on identifying new markets/opportunities in a climate context (*paradox of justification*)	Firm E has a dedicated fund for climate-oriented innovations, and most firms have a form of venture branch to explore new, longer-term innovations
	Ring-fencing climate-oriented innovations that are high-risk but potentially high-reward (*paradox of justification*) through ventures and other collaboration structures (*paradoxes of internal and external alignment*)	Firm A uses different organizational structures, both internally and externally, to reduce risks of the exploration of new climate-oriented innovations
Contextual	Skill development for innovation staff on climate concerns and indicators to increase alertness on climate opportunities and risks (*paradox of internal alignment*)	Several firms dedicate resources to increasing their staff's climate sensitivity in their innovation efforts, often in the context of mainstreaming efforts (Firm F, A, B, and G)
	Interaction with peers through sector initiatives or associations, and depending on the firm's needs, explore opportunities for collaboration (*paradox of external alignment*)	Firm F interacts with peers to discuss their assessments to compare and strategize for internal priorities for emission reduction of their products, whereas Firm C pursues both collaboration and competition, depending on their own needs and available resources
	Combining indicators for accountability and reporting with evidence generation for learning in innovation projects (*paradox of evidence*)	Firm B is exploring new piloting schemes to both identify ways to measure the impacts of products for accountability purposes, as well as opportunities to improve their products
Temporal	Cycling between collaboration on evolving innovations/regulations to crowd in resources and focusing on internal capacity development to ensure competitiveness (*paradox of external alignment*)	Firm C collaborates with peers and researchers on new challenges, but then protects the skills and results from the wider public to develop a competitive advantage

Data availability statement

The datasets presented in this article are not readily available because the generated datasets from this study consist of anonymized interview transcripts with professionals from major agri-food firms. These datasets contain sensitive information regarding company strategies and operations. Therefore, access to these datasets is restricted to ensure confidentiality and to protect the privacy and proprietary information of the participating companies. Researchers interested in accessing the data may request it from the corresponding author, subject to approval. Requests to access the datasets should be directed to leanne@clim-eat.org.

Author contributions

LZ: Conceptualization, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. DD: Supervision, Writing – review & editing. SV: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., and Overy, P. (2016). Sustainability-oriented innovation: a systematic review. *Int. J. Manag. Rev.* 18, 180–205. doi: 10.1111/ijmr.12068

Altunay, M., and Bergek, A. (2023). Interaction between energy incumbents and solar entrants: relationship status complicated. *Environ. Innov. Soc. Trans.* 46:100695. doi: 10.1016/j.eist.2023.100695

Anderson, C. R., and Maughan, C. (2021). "The innovation imperative": the struggle over agroecology in the international food policy arena. *Front. Sustain. Food Syst.* 5:619185. doi: 10.3389/fsufs.2021.619185

Andriopoulos, C., and Lewis, M. W. (2009). Exploitation-exploration tensions and organizational ambidexterity: managing paradoxes of innovation. *Organ. Sci.* 20, 696–717. doi: 10.1287/orsc.1080.0406

Andriopoulos, C., and Lewis, M. W. (2010). Managing innovation paradoxes: ambidexterity lessons from leading product design companies. *Long Range Plan.* 43, 104–122. doi: 10.1016/j.lrp.2009.08.003

Barrett, C. B., Benton, T., Fanzo, J., Herrero, M., Nelson, R. J., Bageant, E., et al. (2022). "A profuse pipeline of promising options" in Socio-technical innovation bundles for Agri-food systems transformation (Cham: Springer International Publishing), 73–158.

Béné, C. (2022). Why the great food transformation may not happen – a deep-dive into our food systems' political economy, controversies and politics of evidence. *World Dev.* 154:105881. doi: 10.1016/j.worlddev.2022.105881

Bohnsack, R., Kolk, A., Pinkse, J., and Bidmon, C. M. (2020). Driving the electric bandwagon: the dynamics of incumbents' sustainable innovation. *Bus. Strateg. Environ.* 29, 727–743. doi: 10.1002/bse.2430

Boons, F., Montalvo, C., Quist, J., and Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview. *J. Clean. Prod.* 45, 1–8. doi: 10.1016/j.jclepro.2012.08.013

Bulah, B. M., Tziva, M., Bidmon, C., and Hekkert, M. P. (2023). Incumbent entry modes and entry timing in sustainable niches: the plant-based protein transition in the United States, Netherlands, and United Kingdom. *Environ. Innov. Soc. Trans.* 48:100735. doi: 10.1016/j.eist.2023.100735

Canfield, M. C., Anderson, M. D., and McMichael, P. (2021a). UN food systems summit 2021: dismantling democracy and resetting corporate control of food systems. *Front. Sustain. Food Syst.* 5:661552. doi: 10.3389/fsufs.2021.661552

Canfield, M. C., Duncan, J., and Claeys, P. (2021b). Reconfiguring food systems governance: the UNFSS and the Battle over Authority and legitimacy. *Development* 64, 181–191. doi: 10.1057/s41301-021-00312-1

Carmine, S., and De Marchi, V. (2023). Reviewing paradox theory in corporate sustainability toward a systems perspective. *J. Bus. Ethics* 184, 139–158. doi: 10.1007/s10551-022-05112-2

Cillo, V., Petruzzelli, A. M., Ardito, L., and Del Giudice, M. (2019). Understanding sustainable innovation: a systematic literature review. *Corp. Soc. Responsib. Environ. Manag.* 26, 1012–1025. doi: 10.1002/csr.1783

Clapp, J. (2021). The problem with growing corporate concentration and power in the global food system. *Nat. Food* 2, 404–408. doi: 10.1038/s43016-021-00297-7

Clapp, J. (2022). "The rise of big food and agriculture: corporate influence in the food system" in A research agenda for food systems. ed. C. L. Sage (Massachusetts: Edward Elgar Publishing), 45–66.

Clapp, J., and Scrinis, G. (2017). Big food, Nutritionism, and corporate power. *Globalizations* 14, 578–595. doi: 10.1080/14747731.2016.1239806

Conti, C., Zanello, G., and Hall, A. (2021). Why are Agri-food systems resistant to new directions of change?A systematic review. *Global Food Sec.* 31:100576. doi: 10.1016/j.gfs.2021.100576

COP28 Presidency. (2023). COP28 calls on governments to ensure food systems and agriculture are central to climate action efforts. Available at: https://www.prnewswire.com/in/news-releases/cop28-calls-on-governments-to-ensure-food-systems-and-agriculture-are-central-to-climate-action-efforts-301884207.html (Accessed May 10, 2024).

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., and Leip, A. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nat. Food* 2, 198–209. doi: 10.1038/s43016-021-00225-9

De Schutter, O. (2017). The political economy of food systems reform. *Eur. Rev. Agric. Econ.* 44, 705–731. doi: 10.1093/erae/jbx009

Erdogan, I., Rondi, E., and De Massis, A. (2020). Managing the tradition and innovation paradox in family firms: a family imprinting perspective. *Entrep. Theory Pract.* 44, 20–54. doi: 10.1177/1042258719839712

Faling, M., Schouten, G., and Vellema, S. (2023). Navigating competing demands in monitoring and evaluation: five key paradoxes. *Evaluation* 30, 211–231. doi: 10.1177/13563890231215075

Friedrich, J., Faust, H., and Zscheischler, J. (2023). Incumbents' in/ability to drive endogenous sustainability transitions in livestock farming: lessons from Rotenburg (Germany). *Environ. Innov. Soc. Trans.* 48:100756. doi: 10.1016/j.eist.2023.100756

Fuglie, K. (2016). The growing role of the private sector in agricultural research and development world-wide. *Glob. Food Sec.* 10, 29–38. doi: 10.1016/j.gfs.2016.07.005

Fuglie, K., Heisey, P. W., King, J. L., Pray, C. E., Day-Rubenstein, K., Schimmelpfenning, D., et al. (2011). Research investments and market structure in the food processing, Agricultural input, and biofuel industries worldwide (U.S. Dept. of Agriculture, Economic Research Services. 130; Economic Research Report).

Fuglie, K., and Toole, A. A. (2014). The evolving institutional structure of public and private agricultural research. *Am. J. Agric. Econ.* 96, 862–883. doi: 10.1093/ajae/aat107

Gonera, A., Nykamp, H. A., and Carraresi, L. (2023). Incumbents' capabilities for sustainability-oriented innovation in the Norwegian food sector—an integrated framework. *Circ. Econ. Sustain.* 3, 1299–1326. doi: 10.1007/s43615-022-00234-1

Gupta, A. K., Smit, K. G., and Shalley, C. E. (2006). The interplay between exploration and exploitation. *Acad. Manag. J.* 49, 693–706. doi: 10.5465/amj.2006.22083026

Guston, D. H. (2001). Boundary organizations in environmental policy and science: an introduction. *Technol. Hum. Values* 26, 399–408. doi: 10.1177/016224390102600401

Hackfort, S. (2023). Unlocking sustainability? The power of corporate lock-ins and how they shape digital agriculture in Germany. *J. Rural. Stud.* 101:103065. doi: 10.1016/j.jrurstud.2023.103065

Hahn, T., Figge, F., Pinkse, J., and Preuss, L. (2018). A paradox perspective on corporate sustainability: descriptive, instrumental, and normative aspects. *J. Bus. Ethics* 148, 235–248. doi: 10.1007/s10551-017-3587-2

Hellin, J., Fisher, E., and Bonatti, M. (2024). Transforming agricultural research and development systems to meet 21st century needs for climate action. *Front. Sustain. Food Syst.* 8:1398079. doi: 10.3389/fsufs.2024.1398079

Karimi Takalo, S., Sayyadi Tooranloo, H., and Shahabaldini Parizi, Z. (2021). Green innovation: a systematic literature review. *J. Clean. Prod.* 279:122474. doi: 10.1016/j.jclepro.2020.122474

Kungl, G. (2024). Challenges of the current discourse on incumbent firms in sustainability transitions. *Energy Res. Soc. Sci.* 108:103367. doi: 10.1016/j.erss.2023.103367

Labarthe, P., Coléno, F., Enjalbert, J., Fugeray-Scarbel, A., Hannachi, M., and Lemarié, S. (2021). Exploration, exploitation and environmental innovation in agriculture. The case of variety mixture in France and Denmark. *Technol. Forecast. Soc. Chang.* 172:121028. doi: 10.1016/j.techfore.2021.121028

Leach, M., Nisbett, N., Cabral, L., Harris, J., Hossain, N., and Thompson, J. (2020). Food politics and development. *World Dev.* 134:105024. doi: 10.1016/j.worlddev.2020.105024

Lee, W. J., Juskenaite, I., and Mwebaza, R. (2021). Public–Private Partnerships for Climate Technology Transfer and Innovation: Lessons from the Climate Technology Centre and Network. *Sustain. For.* 13:3185. doi: 10.3390/su13063185

Lewis, M. W. (2000). Exploring paradox: toward a more comprehensive guide. *Acad. Manag. Rev.* 25:760. doi: 10.2307/259204

Lubberink, R., Blok, V., van Ophem, J., and Omta, O. (2017). Lessons for responsible innovation in the business context: a systematic literature review of responsible, social and sustainable innovation practices. *Sustain. For.* 9:721. doi: 10.3390/su9050721

Magnusson, T., and Werner, V. (2023). Conceptualisations of incumbent firms in sustainability transitions: insights from organisation theory and a systematic literature review. *Bus. Strateg. Environ.* 32, 903–919. doi: 10.1002/bse.3081

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organ. Sci.* 2, 71–87. doi: 10.1287/orsc.2.1.71

McCambridge, J., Mialon, M., and Hawkins, B. (2018). Alcohol industry involvement in policymaking: a systematic review. *Addiction* 113, 1571–1584. doi: 10.1111/add.14216

Moberg, E., Allison, E. H., Harl, H. K., Arbow, T., Almaraz, M., Dixon, J., et al. (2021). Combined innovations in public policy, the private sector and culture can drive sustainability transitions in food systems. *Nat. Food* 2, 282–290. doi: 10.1038/s43016-021-00261-5

Montenegro de Wit, M., and Iles, A. (2021). Woke science and the 4th industrial revolution: inside the making of UNFSS knowledge. *Development* 64, 199–211. doi: 10.1057/s41301-021-00314-z

Moodie, R., Bennett, E., Kwong, E. J. L., Santos, T. M., Pratiwi, L., Williams, J., et al. (2021). Ultra-processed profits: the political economy of countering the global spread of ultra-processed foods – a synthesis review on the market and political practices of transnational food corporations and strategic public health responses. *Int. J. Health Policy Manag.* 10, 968–982. doi: 10.34172/ijhpm.2021.45

Mylan, J., Morris, C., Beech, E., and Geels, F. W. (2019). Rage against the regime: niche-regime interactions in the societal embedding of plant-based milk. *Environ. Innov. Soc. Trans.* 31, 233–247. doi: 10.1016/j.eist.2018.11.001

Papachroni, A., Heracleous, L., and Paroutis, S. (2015). Organizational ambidexterity through the Lens of paradox theory. *J. Appl. Behav. Sci.* 51, 71–93. doi: 10.1177/0021886314553101

Pardey, P. G., Chan-Kang, C., Dehmer, S. P., and Beddow, J. M. (2016). Agricultural R&D is on the move. *Nature* 537, 301–303. doi: 10.1038/537301a

Reinertsen, H., Bjørkdahl, K., and McNeill, D. (2022). Accountability versus learning in aid evaluation: a practice-oriented exploration of persistent dilemmas. *Evaluation* 28, 356–378. doi: 10.1177/13563890221100848

Rosegrant, M. W., Sulser, T. B., and Wiebe, K. (2022). Global investment gap in agricultural research and innovation to meet sustainable development goals for hunger and Paris agreement climate change mitigation. *Front. Sustain. Food Syst.* 6:965767. doi: 10.3389/fsufs.2022.965767

Savell, E., Gilmore, A. B., and Fooks, G. (2014). How does the tobacco industry attempt to influence marketing regulations? A systematic review. *PLoS One* 9:e87389. doi: 10.1371/journal.pone.0087389

Schut, M., Leeuwis, C., and Thiele, G. (2020). Science of scaling: understanding and guiding the scaling of innovation for societal outcomes. *Agric. Syst.* 184:102908. doi: 10.1016/j.agsy.2020.102908

Scott, C. (2018). Sustainably sourced junk food? Big food and the challenge of sustainable diets. *Glob. Environ. Polit.* 18, 93–113. doi: 10.1162/glep_a_00458

Smink, M. M., Hekkert, M. P., and Negro, S. O. (2015). Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies. *Bus. Strateg. Environ.* 24, 86–101. doi: 10.1002/bse.1808

Smith, W., and Lewis, M. W. (2011). Toward a theory of paradox: a dynamic equilibrium model of organizing. *Acad. Manag. Rev.* 36, 381–403. doi: 10.5465/AMR.2011.59330958

Smith, P., and Olesen, J. E. (2010). Synergies between the mitigation of, and adaptation to, climate change in agriculture. *J. Agric. Sci.* 148, 543–552. doi: 10.1017/S0021859610000341

Smyth, S. J., Webb, S. R., and Phillips, P. W. B. (2021). The role of public-private partnerships in improving global food security. *Glob. Food Sec.* 31:100588. doi: 10.1016/j.gfs.2021.100588

Tol, R. S. J. (2005). Adaptation and mitigation: trade-offs in substance and methods. *Environ. Sci. Pol.* 8, 572–578. doi: 10.1016/j.envsci.2005.06.011

Turner, J. A., Klerkx, L., White, T., Nelson, T., Everett-Hincks, J., Mackay, A., et al. (2017). Unpacking systemic innovation capacity as strategic ambidexterity: how projects dynamically configure capabilities for agricultural innovation. *Land Use Policy* 68, 503–523. doi: 10.1016/j.landusepol.2017.07.054

Turnheim, B., and Geels, F. W. (2019). Incumbent actors, guided search paths, and landmark projects in infra-system transitions: re-thinking strategic niche management with a case study of French tramway diffusion (1971–2016). *Res. Policy* 48, 1412–1428. doi: 10.1016/j.respol.2019.02.002

Turnheim, B., and Sovacool, B. K. (2020). Forever stuck in old ways? Pluralising incumbencies in sustainability transitions. *Environ. Innov. Soc. Trans.* 35, 180–184. doi: 10.1016/j.eist.2019.10.012

United Nations. (2021). Nearly 300 commitments from civil society, farmers, youth and indigenous peoples and member states highlights Summit's inclusive process to accelerate action. Available at: https://www.un.org/en/food-systems-summit/news/nearly-300-commitments-civil-society-farmers-youth-and-indigenous-peoples-and (Accessed May 10, 2024).

von Braun, J., Afsana, K., Fresco, L. O., and Hassan, M. H. A. (2023). Science and innovations for food systems transformation. Cham: Springer International Publishing.

Vormedal, I., Bjander, J., Larsen, M. L., and Lindberg, M. B. (2023). Technological change and the politics of Decarbonization: a re-making of vested interests? *Environ. Innov. Soc. Trans.* 47:100725. doi: 10.1016/j.eist.2023.100725

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., et al. (2019). Food in the Anthropocene: the EAT–lancet commission on healthy diets from sustainable food systems. *Lancet* 393, 447–492. doi: 10.1016/S0140-6736(18)31788-4

Woltering, L., Fehlenberg, K., Gerard, B., Ubels, J., and Cooley, L. (2019). Scaling – from "reaching many" to sustainable systems change at scale: a critical shift in mindset. *Agric. Syst.* 176:102652. doi: 10.1016/j.agsy.2019.102652