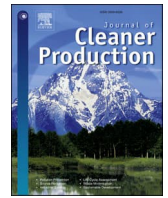


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# Keeping up with the decarbonization: Conceptualizing and investigating incumbents' responses to transition pressures in the post-Paris world

Ella Tolonen

School of Technology and Innovations, University of Vaasa, Wolffintie 34, Vaasa, Finland

## ABSTRACT

Incumbents are central regime actors who simultaneously adapt to transitions and actively shape them. This study has two objectives: advance the conceptualization around these actors' behaviors in contemporary transition processes and demonstrate a novel research approach to study this behavior in practice. The focus is on incumbents' responses to transition-related external pressures. These responses are studied by reviewing related work from organization and management literature, as well as conducting an empirical case study in the aviation sector. The theoretical and empirical insights are combined through flexible pattern matching into a conceptual framework, which simultaneously accommodates a holistic view of different types of responses incumbents use to navigate the complex operating environment, while also supporting particularity that goes beyond strategy talk. For the empirical investigation, this research utilizes incumbent airlines' transition risk work as a source of information on what external pressures these actors themselves perceive and the responses they operationalize. The empirical case study illustrates how by distinguishing between standard, inconsistent, and unconventional response areas that incumbents take part in, even a snapshot analysis of a contemporary transition phenomenon can reveal what is happening in socio-technical regimes. The analysis also pinpoints how responses have two important characteristics that signify the importance of acknowledging the variety of responses that incumbents have at their disposal: multi-functionality and parallelity. Together, the insights of this paper can support the study and understanding of the complex, heterogeneous, and nuanced behavior of incumbent organizations, and encourage more research efforts on transitions in the making.

## 1. Introduction

Low-carbon transitions are complex multi-actor processes which are socially constructed and co-produced through the everyday practices and decisions of different actors (Köhler et al., 2019). There is a global consensus around the need to reduce greenhouse gases quickly and vigorously, as outlined in the Paris Agreement, but exactly how this should be done remains subject to large debates. Prevailing incumbent organizations are central to influencing the speed and direction of sustainability transitions with their behavior, while having to navigate a complex web of risks and opportunities to remain profitable and relevant (Roman Pais Seles et al., 2018). Incumbents thus simultaneously adapt to transitions and actively shape them (Geels, 2014a), resulting in a bi-directional dynamic between external pressures and incumbents' responses to these pressures that is a central mechanism in transitions (Turnheim and Geels, 2013). In this vein, several scholars in the field of transition research have argued that the role and behavior of incumbent organizations are in practice, much more heterogeneous, nuanced, and complex than is generally assumed in the transition literature and theorizing, and that acknowledging and understanding this is essential

in advancing transition research (Berggren et al., 2015; Karltorp and Sandén, 2012; Steen and Weaver, 2017; Turnheim and Sovacool, 2020). This has prompted a lot of research attention and efforts to conceptualize agency in general (e.g., De Haan and Rotmans, 2018; Huttunen et al., 2021) and incumbency in particular (e.g., Kump, 2023; Kungl, 2024; Magnusson and Werner, 2023; van Mossel et al., 2018).

The empirical approaches for studying incumbency are still largely dominated by longitudinal case studies that examine these actors' behavior in historical transition processes (e.g., Ferguson-Cradler, 2022; Geels and Gregory, 2023; Gregory and Geels, 2024; Kattirtzi et al., 2021; Markard et al., 2021; Mori, 2021), but more efforts to study incumbents also in the present and recent past in relation to transitions in the making have emerged (e.g., Friedrich et al., 2023; Smink et al., 2013; Trencher et al., 2024) and been called for (Köhler et al., 2019). The longitudinal case studies have shed light on how previous transitions have unfolded in different sectors, and the variety of response strategies to external pressures that incumbents have deployed throughout them. These studies often follow the Triple Embeddedness Framework (Geels, 2014a), which analyze incumbents' responses in terms of different socio-cultural strategies, political strategies, innovation strategies, and

*Abbreviations:* AF-KLM, Air France – KLM; CDP, Carbon Disclosure Project; CORSIA, Carbon Offsetting and Reduction Scheme for International Aviation; DILC, Dialectic Issue Lifecycle Model; ETS, Emission Trading Scheme; IAG, International Airlines Group; SAF, Sustainable Aviation Fuel; TEF, Triple Embeddedness Framework.

*E-mail address:* [ella.tolonen@uwasa.fi](mailto:ella.tolonen@uwasa.fi).

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economic positioning strategies. The more contemporary transitions in the making research, on the other hand, tends to focus on exploring either specific types of response strategies more in detail (e.g. discourse, innovation, or policy-related responses) or responses in regard to a specific firm ambition (e.g. delay transition), often over a short time-frame. Longitudinal research thus observes incumbents' behavior across different operational areas, whereas contemporary studies zoom into specific types of behavior.

Due to the urgency to decarbonize our societies, there is a need to expand existing empirical approaches and conceptual tools for studying incumbents' behavior in contemporary transition processes currently in motion, in order to better understand these actors' complex role in transitions (Kungl, 2024; Turnheim and Sovacool, 2020). What is missing from the current literature is an approach to study transitions in the making that bridges the benefits of the traditional longitudinal case studies and the contemporary ones. That is, an approach that enables holistic exploration of incumbents' behavior across different types of responses, while also supporting particularity. This is restraining the study and understanding of incumbent organizations' behavior in the contemporary transition processes unfolding around us, and consequently, research on destabilization of socio-technical systems.

To fill this void, this paper advances conceptualization around incumbents' responses to transition-related external pressures, and demonstrates a novel empirical research approach to study this in practice in a sector where transition is currently in motion. By using flexible pattern matching, existing work on incumbents' responses both in transition research as well as organization and management studies is explored to guide a case study in the European aviation sector. The case study simultaneously contributes to the conceptual work, as well as pilots the utilization of companies' transition risk disclosures to study their behavior. These disclosures contain information on the external pressures incumbents perceive in their operating environment and the responses they consider appropriate, making them a valuable resource for future research.

This research simultaneously pursues two of the methodological research directions as outlined in the transition research agenda (Köhler et al., 2019): expanding inquiry to transitions in the making, and paying attention to particularity whilst developing generic insight. The developed conceptual framework and piloted empirical research approach can both practically guide future research endeavors on incumbents' behavior that dig deeper into the complex, nuanced and heterogeneous nature of responses that incumbents employ to keep up with the decarbonization in the post-Paris world.

## 2. Theoretical points of departure

### 2.1. Destabilization

In transition research, the prominent set of rules embedded in a socio-technical system, which guide its functions, is referred to as a regime (Geels, 2002). Regime destabilization is a prerequisite for any socio-technical transition. It is a longitudinal process, driven by three forms of interaction: the accumulation of external pressures in the economic or socio-political environment, responses from the regime actors, and weakening organizational commitment (Turnheim and Geels, 2013). The accumulation of external pressures can have a negative influence on resource flows or regime legitimacy, which can result in performance problems. The performance problems can be addressed through various responses by the regime actors. However, the responses may not be adequate to mitigate the external pressures, or may trigger unexpected new pressures, leading to additional performance problems. The chaining of performance problems due to insufficient responses can lead to weakening regime commitment, and prompt regime actors to look for alternative responses to stop the cycle. The first sign of destabilization is when this search for responses becomes more distant from the established socio-technical configurations in the regime, and once

regime actors start to question the core beliefs of the system destabilization is in full bloom.

### 2.2. Incumbents' behavior

Incumbent organizations are important regime actors and often portrayed as their backbone (Karlton and Sandén, 2012). They are generally regarded as the well-established, affluent, and central actors in socio-technical systems, with vested interests and core capabilities. As notable users of power and with much at stake in maintaining the dominance of established socio-technical configurations, incumbents provide an excellent entry point for studying destabilization (Turnheim, 2022). Incumbents can develop diverging trajectories and alternative socio-technical solutions in response to the same set of external pressures, resulting in heterogeneous behavior (Geels, 2014a; Karlton and Sandén, 2012; Kuokkanen et al., 2018). This heterogeneity is one of the motors of regime fragmentation that feeds destabilization (Karlton and Sandén, 2012; Mori, 2021), indicating weakening commitment and more elaborate search for alternatives. The type of transition that unfolds from regime destabilization, therefore, depends to a great extent on how different incumbent actors decide to and can respond to the external pressures (Geels and Schot, 2007).

Mori has proposed that the reasons behind incumbents' heterogeneous behavior in the same transition contexts can be categorized into firm-specific factors, socio-economic factors, and institutional and policy factors (Mori, 2021). For this paper, the notion of firm-specific factors is especially relevant. It signifies that incumbents have different perceptions of what external pressures they face and how to deal with them. This interpretation and translation of external pressures into a strategic operational environment is central to transitions (Geels, 2014a), as it is the internalization of external pressures by different regime actors that leads to diverging responses (Kuokkanen et al., 2018). In other words, how an actor perceives their operating environment and the external pressures that it poses influences the responses they see as legitimate in that context.

When a socio-technical regime is destabilizing, it faces challenges that are significant enough to threaten its established functions and very existence (Turnheim, 2022). Because destabilization can directly influence the position of incumbents, it is evident that these actors try to obstruct or at least to some extent control this process (e.g., Geels, 2014b; Hess, 2016; Smink et al., 2013; Ting and Byrne, 2020). Despite this, incumbents are not viewed solely as villains that try to block transition processes and lock in the current regime, but they may also actively foster change and innovation at the niche level (e.g., Apajalahti et al., 2018; Berggren et al., 2015; Steen and Weaver, 2017), although scholars mostly agree that incumbents are more inclined to develop their existing operations and engage in incremental innovation.

Most studies on firms' behavior in contemporary transition processes have typically focused either on a specific objective that guides these actors' behavior or investigated a certain type of firm behavior in detail. For example, Smink et al. (2013), Hess (2016), Apajalahti et al. (2018), and Ting and Byrne (2020) studied incumbents' strategies to resist, shape, or control the development of niches, whereas Steen and Weaver (2017) and Onufrey and Bergek (2021) looked into activities related to innovation and diversification, and Bosman et al. (2014) and Lee and Hess (2019) targeted only incumbents' discursive strategies. However, in reality, incumbents' behavior might be more complex than portrayed in these papers, when considering that incumbents can also shift their strategic focus over time and simultaneously participate in multiple modes of behavior (Penna and Geels, 2015; van Mossel et al., 2018). There is thus a need to continue research efforts on incumbents' behavior and develop more nuanced and dynamic approaches for studying it (Turnheim and Sovacool, 2020).

### 2.3. Zooming into pressures and responses

The constructs of external pressures and incumbents' responses, as well as the relationship between the two, have been theorized most vigorously in the Triple Embeddedness Framework (TEF) by Geels (2014a) and the Dialectic Issue Lifecycle Model (DILC) by Penna and Geels (2012). The TEF conceptualizes how firms are embedded in two external environments in which the external pressures manifest: the socio-political and the economic. Here, the socio-political environment refers to the institutional environment, in which incumbents' legitimacy and 'license to operate' are formulated among various stakeholders, whereas the economic environment includes the various economic transactions between competitors, suppliers, and customers which shape profitability (Penna and Geels, 2012). The DILC-model builds on top of this notion, and further conceptualizes how the struggles between external pressures and industry responses develop over time: socio-political pressures from activist spill over to public opinion and ultimately, political agendas, after which economic pressures emerge due to new regulation and changing consumer preferences.

According to these authors, the firms in industries can employ four types of strategies to respond to the external pressures (Penna and Geels, 2012). These are socio-cultural strategies, political strategies, innovation strategies, and economic positioning strategies. The DILC-model distinguishes between symbolic and substantive actions as a response to external pressures and proposes that the different types of actions also follow a regular pattern, from the socio-cultural to the economic. The model has been complemented later on by suggesting, for example, that innovation strategies can also be applied at earlier phases for symbolic purposes (Penna and Geels, 2015), and that the phases of accumulation of external pressures can also move backwards (Geels and Penna, 2015). The interplay between external pressures and responses as presented in these bodies of work is visualized in Fig. 1.

Both TEF and DILC focus on discovering how external pressures and responses develop over time. Especially TEF has become a prominent theory in transition research which has been operationalized in numerous longitudinal studies in the field (e.g., Brauers et al., 2020; Canal Vieira et al., 2022; Geels and Gregory, 2023; Gregory and Geels, 2024; Kungl and Geels, 2018; Sovacool et al., 2017), which typically investigate developments over several decades and shed light on how previous transition processes have unfolded in different sectors. However, by obtaining a longitudinal perspective to transitions and a broad but high-level view on the different types of responses that have occurred throughout these transition processes, this approach is not directly suitable for studying incumbents' behavior in transitions in the making. The following two sections discuss parallel conceptualizations of external pressures and responses outside the field of transition research, which are well-suited to support and complement more contemporary research approaches that build on TEF and DILC.

#### 2.3.1. External pressures as transition risks

Transition risks are climate-related business risks that emerge when societies transition to low carbon. The concept originates from the financial sector and has within the past few years become part of the bread-and-butter of incumbent organizations' corporate responsibility work. Transition risks are often categorized into policy and legal, market, technology, and reputation-related risks (TCFD, 2017). Policy and legal risks include, for example, new mandates and regulations on existing products, whereas technological risks include risks related to the development and acquisition of low-carbon alternatives. Market risks have directly to do with changing customer behavior, competition, and changes in the supply chain, which relates closely to reputation risks that refer to sudden shifts in consumer preferences and stigmatization. With these five sub-categories, the concept of transition risk effectively captures different transition-related external pressures that organizations might face in the low-carbon transition, much in line with the pressures conceptualized in TEF.

Incumbents across sectors are facing increasing demands from investors (Ilhan et al., 2022) and regulators (*Corporate Sustainability Reporting*, n.d.) to disclose information on their transition risks work and strategies to combat the risks they identify, in order to enable these actors to evaluate how future-proof the companies' operations are. Disclosing transition risk information is thus the incumbents' way to ensure their stakeholders that they take decarbonization and the related economic and socio-political pressures on their business seriously. As this is the purpose of the response accounts, they provide rather detailed information on how these actors perceive the operating environment and the variety of related activities that the incumbents engage in at a given time. Utilizing incumbents' transition risk work to study external pressures and responses could thus provide a new source of information to enrich empirical inquiries in transition research.

#### 2.3.2. Responses as specific activities

The conceptualizations of response strategies introduced in the TEF have been developed based on both strategy and organizational theory (Geels, 2014a). Already in 2002, there were over 50 different models and typologies in organization and management literature for classifying corporate strategies in relation to climate change (Kolk and Mauser, 2002). This research is highly interested in understanding the sources and mechanisms of climate-related pressures on business and the prominent strategies for companies to manage them (Unter et al., 2023). Within this literature, using the term 'responses' to refer to organizational behavior is common, although often ill-defined. The term refers to an organization's actions in relation to a specific phenomenon, but it can be operationalized either on a general strategy level or on a more detailed activity level, often implicitly. There are several papers that have provided overviews or taxonomies of the types of responses<sup>1</sup> companies can engage in due to climate change-related pressures (e.g., Cadez and Czerny, 2016; Jeswani et al., 2008; S. Lee, 2012; Lewandowski and Ullrich, 2023; Sprengel and Busch, 2010).

According to the latter view focusing on the activity level, organizational responses are seen as individual building blocks that together construct the overall corporate strategy (Sprengel and Busch, 2010), reflecting the standard definition of strategy as the 'pattern in action over time'. Responses are thus the manifestation of what the organizations do, not what they aspire to be. They are factual retrospective activities that can be observed, measured, and analyzed. By investigating a company's individual responses, it is possible to grasp its overall strategy in practice. This view from the organization and management literature suggests how there is potential to extend conceptualization regarding responses in transition research also towards a more detailed activity level, which could in turn further support the study of incumbents' behavior.

## 3. Material and methods

To explore incumbents' responses, this research adapted a flexible pattern matching method described by Bouncken et al. (2021). It enables the combination of theoretical and empirical observations through continuous iterations, starting from the theoretical pattern as a backbone that guides further empirical investigation (Sinkovics, 2018). The streamlined research process has three main phases: theoretical investigation, empirical investigation, and final pattern matching.

### 3.1. Theoretical investigation

In theoretical investigation, existing work on incumbents' responses

<sup>1</sup> It must be noted that the terms 'measures' and 'practices' are also used rather synonymously with the concept of 'responses' in the organization and management literature. For example, Cadez and Czerny (2016) talk about 'carbon practices'.

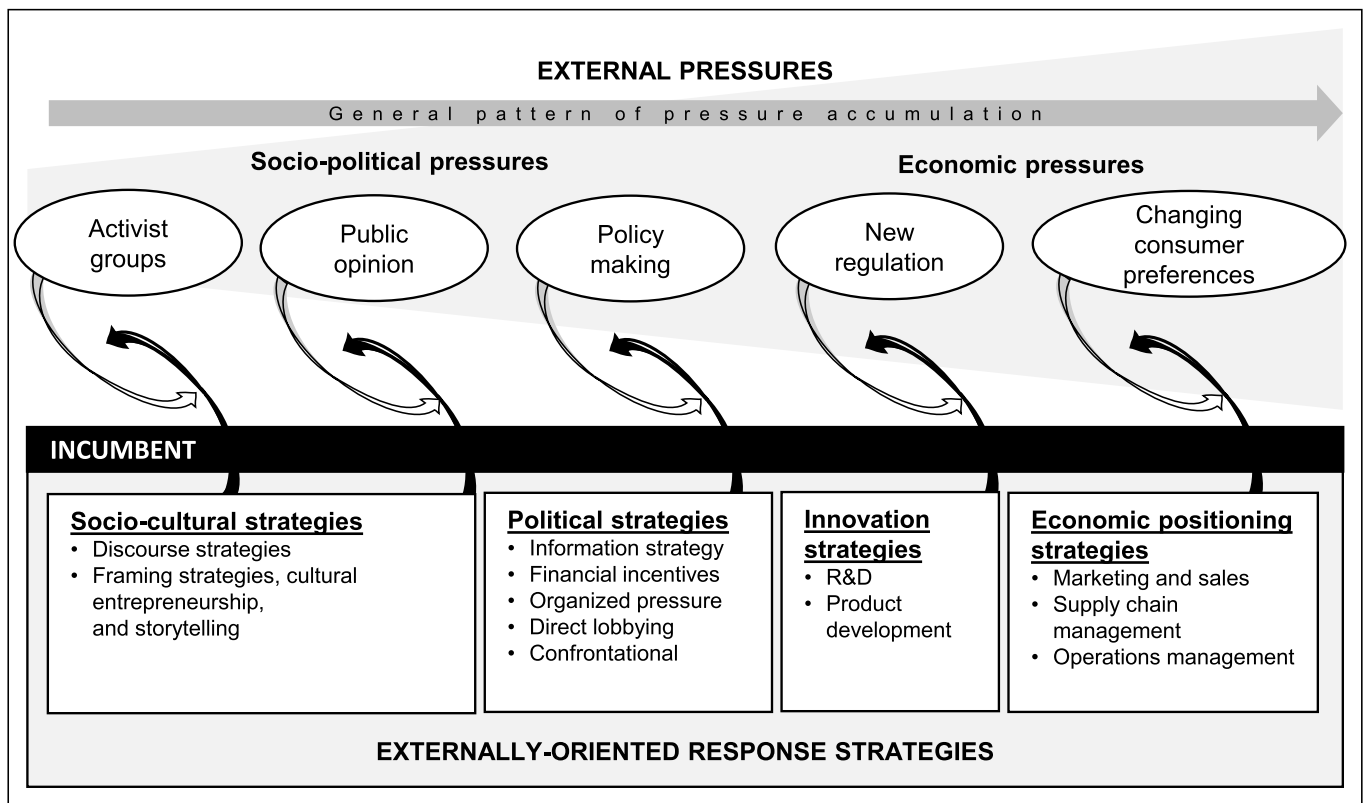


Fig. 1. Simplified view of the interplay between external pressures and externally oriented response strategies, based on the combined insights from Geels (2014a) and Penna and Geels (2012).

to external pressures was reviewed in transition literature, as well as in organizational and management literature, to construct the theoretical pattern. The review performed in the theoretical investigation was exploratory rather than systematic, and relevant work was identified by reviewing papers found in various research databases as well as by snowballing.

The primary theoretical pattern that guided the first round of empirical investigation was loosely following the four response strategies described by Penna and Geels (2012). After the first round of empirical investigation, the theoretical investigation was extended to organization and management literature which addresses the same phenomenon of organizations taking actions in relation to low-carbon transition-related pressures, and tends to look into specific firm level activities in doing so. As the term ‘response’ is quite ambiguous and not well established, papers that used different terminology than regime/incumbent/organizational responses to conceptualize the phenomenon were also considered.

### 3.2. Empirical investigation

The empirical investigation was conducted on the field-level among companies operating in the European aviation sector. For identifying the transition-related external pressures that the incumbents perceive in their operating environment, and consequently the responses they have applied, this paper looked into these companies’ transition risk work as reported for the Carbon Disclosure Project (CDP).<sup>2</sup>

<sup>2</sup> The CDP has since 2018 provided companies with a platform that has structured disclosure protocol which fully aligns with the recommendations formulated by The Task Force for Climate-related Financial Disclosures (TCFD) in 2017. CDP includes the world’s largest TCFD-aligned database, and its scores are used widely in decision-making by financial actors.

The preconditions for the case selection were that an airline is a member of the Airlines for Europe Association<sup>3</sup> (A4E), which represents over 70% of European air traffic, and disclosed its activities to the CDP’s Climate Change questionnaire in 2022. Seven airlines met these criteria: EasyJet, Finnair, International Airlines Group (IAG), Air France-KLM Group (AF-KLM), Lufthansa, Norwegian, and Ryanair. Although all the qualitative information provided in the disclosure documents has been reviewed, the analytical focus remained in section two on transition risks and opportunities, section three on business strategy, and section four on targets and performance. A light review of annual reports for 2021 and other company-produced materials accompanied the CDP data where appropriate (e.g., if the airline directly refers to information available only in its annual report, or information provided for CDP appears incomplete). These empirical data were coded using NVivo 14.

To draw a clear distinction between the responses related to a uniform regime response and those that may signal regime fragmentation, the identified responses were further analyzed and divided into three categories: standard, inconsistent, and unconventional. Standard responses are those the airlines utilized en masse, and thus the backbone of the industry regime’s response to destabilization. The analyzed material distinguished only slight nuances of difference among the standard responses, and the differences that emerged were not confrontational or mutually exclusive. For inconsistent responses, several competing response logics emerged between the companies in relation to a particular phenomenon, which manifested with substantially different responses that were most often exclusionary to one another. Finally, the unconventional responses were adopted by only a minority of companies, without the existence of contesting alternative responses.

<sup>3</sup> It must be noted that Finnair and Norwegian joined A4E after the 2021 reporting period.

**Table 1**

List of responses identified from the organization and management literature.

<b>1. SOCIO-CULTURAL STRATEGIES</b>
<i>Damert et al. (2017)</i> : Stakeholder engagement; Corporate communications
<i>Lé (2013)</i> : Disseminate information and claim climate chain expertise; Engage community stakeholders to negotiate targets; Frame climate change as responsibility of policy makers
<i>Lee (2012)</i> : External relationship development
<i>Sprengel and Busch (2010)</i> : Inform stakeholders of the carbon reduction efforts
<i>Talbot and Boiral (2015)</i> : Communication to argue the rationale of their climate impacts
<b>2. POLITICAL STRATEGIES</b>
<i>Cadez and Czerny (2016)</i> : Government affairs and negotiations
<i>Damert et al. (2017)</i> : Political activities
<i>Lé (2013)</i> : Lobby to co-create policy
<i>Sprengel and Busch (2010)</i> : Engage in the political process
<b>3. INNOVATION STRATEGIES</b>
<i>Cadez and Czerny (2016)</i> : Switching energy source; Efficiency improvements; Combined heat & power; Carbon capture & storage; Use of recycled materials; Material substitution; Making product and process changes; Use of low-carbon technologies; Product output reductions; Discontinuation of production; Supply chain emission reduction downstream and upstream
<i>Damert et al. (2017)</i> : Product improvement; Process improvement; New markets & product development
<i>Jeswani et al. (2008)</i> : Changes in technologies, processes, and materials; Energy efficiency; Networking and research alliances
<i>Kolk and Pinkse (2005)</i> : Process improvement; Product development; Supply chain measures
<i>Lewandowski and Ullrich (2023)</i> : Energy production, acquisition, efficiency, awareness and recovery; Product adaptations; Process efficiency and use of clean fuels; Materials reuse, recycling, reduction, recovery, redesign, and remanufacturing
<i>Lé (2013)</i> : Develop new technologies
<i>Lee (2012)</i> : Product improvement (inc. green marketing practices); Process & supply improvement; New market and business development
<i>Sprengel and Busch (2010)</i> : Increase carbon emission efficiency; Reduce production of carbon intensive products: Become independent of direct carbon emissions
<i>Weinhofer and Hoffmann (2008)</i> : Carbon reduction (Improvement of existing carbon emitting production processes or products); Carbon independence (Addition of new and improvement of existing carbon free production processes or products)
<b>4. ECONOMIC POSITIONING STRATEGIES</b>
<i>Cadez and Czerny (2016)</i> : Transferring production to third country; Carbon trading
<i>Damert et al. (2017)</i> : Carbon compensation
<i>Jeswani et al. (2008)</i> : Participation in Kyoto flexible mechanisms (inc. emission trading); Participation in voluntary programs
<i>Kolk and Pinkse (2005)</i> : Internal transfer of emission reductions; Enter products to a new market; Acquire emission credits
<i>Lewandowski and Ullrich (2023)</i> : Carbon compensation (emission credits trading and offsetting); Carbon capture
<i>Sprengel and Busch (2010)</i> : Increase emission limits by purchasing allowances; Explore new markets with lower pressures; Outsource emission intensive parts of operations
<i>Weinhofer and Hoffmann (2008)</i> : Acquisition of additional carbon emission capacity through emission trading; Investments in offsetting projects

**Table 2**

Transition risks identified from the airlines' CDP reporting.

Category	Transition risks in the European aviation sector
<b>Policy</b>	<ul style="list-style-type: none"> <li>• Changes in the EU emission trading scheme (incl. phasing out free emission allowances)</li> <li>• National and EU-level blending mandates of sustainable aviation fuel</li> <li>• Expansion of taxes (incl. kerosene tax)</li> <li>• Policy asymmetry</li> <li>• Regulatory duplication</li> <li>• Bans on short-haul travel</li> </ul>
<b>Legal</b>	<ul style="list-style-type: none"> <li>• Shareholder activism</li> <li>• Legal action by civil society and consumer groups</li> <li>• Breach of environmental/climate compliance</li> </ul>
<b>Technology</b>	<ul style="list-style-type: none"> <li>• Lack of ripe technological solutions to replace combustion engines</li> <li>• High prices for lower-emission technologies</li> <li>• Access to sustainable aviation fuels</li> <li>• Sustainable aviation fuel production capacity and supporting infrastructure</li> </ul>
<b>Market</b>	<ul style="list-style-type: none"> <li>• Lost demand due to ethical and sustainability concerns</li> <li>• Changing stakeholder expectations</li> <li>• Access to capital</li> <li>• Increasing competition for voluntary carbon offsets</li> <li>• High prices for emission allowances</li> </ul>
<b>Reputation</b>	<ul style="list-style-type: none"> <li>• Inability to meet new customer and stakeholder expectations</li> <li>• Stigmatization of the sector</li> <li>• Rising greenwashing claims</li> </ul>

## 4. Results

### 4.1. Theoretical insight

The specific activities identified from the organization and management literature were wide-ranging across the [Penna and Geels's \(2012\)](#) four different strategy areas. However, most of these responses had to do with different innovation strategies and economic positioning strategies, while activities related to socio-cultural strategies and

political strategies were less frequently mentioned. The complete list of activities is presented in [Table 1](#).

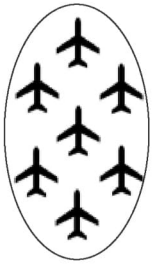
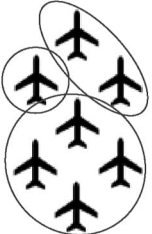

### 4.2. Empirical insight

The picture painted by the airlines' CDP reporting shows a sector that is still in major distress and only starting to recover from the pandemic. Despite this and probably due to the numerous transition risks identified, all the airlines remained committed to decarbonization. The transition risks, listed in [Table 2](#), prompted many standard responses across the four strategy areas. Inconsistencies between the airlines could be primarily traced in niche innovation strategies as well as economic positioning strategies. The only unconventional response distinguished, which was pursued by a single airline, related to economic positioning strategies. Next, the types of responses in these three categories are elaborated more in detail. An overview of the empirical results is presented in [Fig. 2](#).

#### 4.2.1. Standard responses among the airlines

The simplest solution to cut carbon emissions would be to deliberately reduce jet fuel consumption. Three types of standard responses related directly to this emerged from the data. These emission reduction activities mitigate market and reputation related transition risks, by illustrating to stakeholders that the airline is doing its best to decarbonize operations, as well as policy and legal risks by minimizing the use of fossil fuels.

Firstly, all the airlines engaged in several operative responses related to improving energy efficiency of flight operations. For example, operations optimization through pilot training and instructions seeking to reduce fuel burn during flights, route and flight path optimization, aircraft type optimization, and aircraft weight reduction activities. They also systematically placed fleet modernization at the core of their decarbonization strategy, as the 'new generation' aircraft can be up to 20% more energy efficient ([IEA, n.d.](#)). However, the pace at which these new aircraft were introduced into the fleet varied, for example due to

	IDENTIFIED RESPONSES	RELATED PRESSURES														
<b>STANDARD RESPONSES</b>  	<p><b>Optimization of in-flight operations</b> <i>e.g., fleet modernization, pilot training, route and flight optimization, aircraft weight reduction</i></p> <p><b>Retrofits on existing fleet</b></p> <p><b>Early retirement of existing aircraft</b></p> <p><b>Emission reductions in other operational areas</b> <i>e.g., procurement of renewable energy for ground operations, improvement of waste management and recycling</i></p> <p><b>Stakeholder engagement and communication on climate work</b> <i>e.g., inflight material, press releases, reporting climate data, marketing</i></p> <p><b>Direct and indirect lobbying activities</b> <i>on kerosene tax (oppose), reformation of European Air Traffic Management (support), phasing out free emission allowances (oppose)</i></p> <p><b>Hedging emission credits and jet fuel</b></p> <p><b>Fuel-tankering and re-routing</b></p>	<p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p>														
<b>INCONSISTENT RESPONSES</b>  	<p><b>Carbon compensation practices</b></p> <table border="1"> <tr> <td><i>Customer-reliant compensation</i></td> <td><i>Proactive self-compensation</i></td> <td><i>A hybrid response</i></td> </tr> </table> <p><b>Voluntary SAF blending</b></p> <table border="1"> <tr> <td><i>Customers' voluntary SAF procurement</i></td> <td><i>Airlines' voluntary SAF procurement</i></td> <td><i>A hybrid response</i></td> </tr> </table> <p><b>Access to SAF</b></p> <table border="1"> <tr> <td><i>Offtake agreements with SAF suppliers</i></td> <td><i>Direct investments in SAF technology and production</i></td> </tr> </table> <p><b>R&amp;D on novel decarbonization solutions</b></p> <table border="1"> <tr> <td><i>Synthetic fuel production</i></td> <td><i>Redesigned aircraft</i></td> <td><i>Hydrogen engine</i></td> <td><i>Hydrogen-electric aircraft</i></td> </tr> </table> <p><b>Direct and indirect lobbying activities on SAF mandate and EU ETS</b></p> <table border="1"> <tr> <td><i>Advocating coverage of all flights departing from and landing in the EU</i></td> <td><i>Advocating an intra-EU ruling only</i></td> </tr> </table>	<i>Customer-reliant compensation</i>	<i>Proactive self-compensation</i>	<i>A hybrid response</i>	<i>Customers' voluntary SAF procurement</i>	<i>Airlines' voluntary SAF procurement</i>	<i>A hybrid response</i>	<i>Offtake agreements with SAF suppliers</i>	<i>Direct investments in SAF technology and production</i>	<i>Synthetic fuel production</i>	<i>Redesigned aircraft</i>	<i>Hydrogen engine</i>	<i>Hydrogen-electric aircraft</i>	<i>Advocating coverage of all flights departing from and landing in the EU</i>	<i>Advocating an intra-EU ruling only</i>	<p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p> <p>P L T M R</p>
<i>Customer-reliant compensation</i>	<i>Proactive self-compensation</i>	<i>A hybrid response</i>														
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<i>Advocating coverage of all flights departing from and landing in the EU</i>	<i>Advocating an intra-EU ruling only</i>															
<b>UNCONVENTIONAL RESPONSES</b>  	<p><b>Intermodal transportation</b></p>	<p>P L T M R</p>														

= Direct influence on the response     
 (P) = Policy    (L) = Legal    (T) = Technology    (M) = Market    (R) = Reputation  
 = No notable influence on the response

Fig. 2. Overview of the airlines responses and related pressures identified in the empirical study.

firm finances, and only the future will tell whether the plans materialize.

Secondly, closely connected to fleet modernization, is the early retirement of aircraft. All the airlines were seeking to phase out old, less energy-efficient aircraft and replace them with modern vessels. For example, in 2020 IAG accelerated the retirement of 47 aircraft from its fleet, primarily due to the economic challenges presented by COVID-19,

but also to improve the company's carbon performance (CDP World-wide, 2022e). The pandemic undoubtedly had an enormous impact on early retirement decisions, and without the swift fall in passenger numbers such extensive retirement action would likely not have been taken.

Thirdly, a common way to reduce emissions from flight operations is

to retrofit the existing fleet. Integrating existing aircraft models and new technologies, it is possible to improve energy efficiency and lengthen lifecycles, providing a cheaper and faster alternative to fleet renewal. For example, Lufthansa reported it had retrofitted its cargo fleet with a new surface coating that can reduce flight operations' carbon emissions by 1% (CDP Worldwide, 2022b), and Ryanair had retrofitted its fleet with winglets that reduce fuel burn by 5% (CDP Worldwide, 2022g).

Despite the dominance of jet fuel as the main source of emissions, all the airlines were actively reducing emissions in other operational areas, too. This included, for example, the procurement of renewable energy for ground operations, and improvement of waste management and recycling activities both in-ground and in-flight. As the impact of these non-flight responses on absolute emission levels is extremely small, it appears they are primarily targeted towards mitigating reputation and market-related transition risks, by demonstrating companies' commitment to reducing emissions across the whole value chain, and to sustainability in general.

All the airlines actively informed and engaged a variety of stakeholders in their climate work, including the different emission reduction schemes, through different channels. Inflight material, newsletters, press releases, reporting climate-related data, and other engagement campaigns were numerous and common. These responses illustrate a shared interest in keeping customers, shareholders, and policymakers well-informed about their climate-related targets, actions, and performance, in order to counteract market and regulation related pressures such as loss of demand due to sustainability concerns, emerging regulation, and stigmatization of the sector. This closely relates to endeavors to get customers involved in reducing the environmental impact of air travel, such as voluntary compensation schemes and recommendations to pack light and favor direct connections.

Of course, the airlines also strived to influence policy development related to their operations, to mitigate a variety of regulatory risks by lobbying directly or through trade associations. The airlines shared common views on several pressing regulatory issues, such as: incorporating kerosene tax into the Energy Taxation Directive (opposed), reforming European Air Traffic Management (supported), and phasing out free emission allowances (opposed). Much of this lobbying was enacted jointly through A4E. Some airlines also deliberately mentioned that they were trying to influence the development of standardization, such as implementation of the global aircraft carbon certification standard by the International Civil Airline Organization. It is presumed that this behavior is also standard in the sector. Airlines also engaged in more indirect forms of political advocacy by disseminating information in the media. That is, rather than lobbying a specific legislation or policy package already on the table, the companies tried to shape the general issue-solution space and construct a future vision for decarbonizing the sector. These responses could be regarded as more anticipatory, aspiring to proactively influence the substance of the transition risks. Specific advocacy topics mentioned by several airlines included a single global carbon pricing mechanism for aviation, in response to the perceived overlap between Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and EU Emission Trading Scheme (ETS).

To mitigate short-term price volatility in the carbon market and access carbon emission credits at a pre-determined price, the airlines (except Norwegian<sup>4</sup>) reported a hedging strategy for acquiring emission credits under ETS. For example, by the end of 2021 Ryanair had already hedged 90% of its projected carbon needs until the end of 2023 (CDP Worldwide, 2022g). These responses enable airlines to create a small buffer to design more extensive response strategies in case carbon prices skyrocket or there is a supply shortage. For similar reasons, all the airlines were hedging a proportion of their protected jet fuel needs for a 6–24-month period.

<sup>4</sup> Norwegian was in fact demanded to pay around 40 million euros fine for the Norwegian government for not meeting the obligations of the ETS in 2020.

In the absence of globally symmetrical SAF and carbon policies, the airline industry has warned policy makers of the potential increase in fuel tankering and re-routing behavior that could lead to carbon leakage and even increase emissions (Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe, 2021). Fuel tankering is already a standard practice to mitigate regional price differences in the EU - according to Eurocontrol, 21% of all flights in the EU perform full or partial fuel tankering (Eurocontrol, 2019). However, this is perhaps not behavior airlines want to highlight, as only one deliberately mentioned these responses or 'operational decisions' through which they can avoid higher fuel prices.

#### 4.2.2. Inconsistent responses between the airlines

All the airlines highlighted the significance of carbon compensation in reaching their climate targets. Offsetting has a notable role in the sector since there are currently no commercially available technical solutions to radically decarbonize operations. This role has been further cemented by the CORSIA, which will require airlines to offset all growth in carbon emissions beyond 2019 levels between states that have volunteered to participate in the program (IATA, 2023). Acquiring carbon offsets towards CORSIA and other non-regulatory compensation aspirations mitigates market and reputation related pressures, such as the stigmatization of the sector, loss of demand due to sustainability concerns, and the risk of binding regulation.

Three rivaling compensation responses were distinguishable among the airlines: customer-reliant compensation, proactive self-compensation, and a hybrid response. Relying entirely on private and/or corporate customers' voluntary compensation was the most common response option, undertaken by four airlines: Finnair, Lufthansa, Norwegian, and Ryanair. The most unusual response was for a company to proactively self-compensate its carbon emissions on behalf of customers. This behavior was only reported by EasyJet, which had self-offset all its in-flight emissions in 2021, but has since put an end to the practice. Two subsidiaries relied on a hybrid response - AF-KLM's Air France and IAG's British Airways. Both subsidiaries self-offset all in-flight emissions on domestic routes and offer customers the voluntary offsetting option for other routes. It must be noted that, technically, compensation purchased by customers through an airline's offsetting platform can also be counted towards the CORSIA targets, and currently there is very little transparency on who is retiring the carbon credits.

All the airlines besides EasyJet placed SAFs at the heart of their emission reduction strategy. In 2022, the EU-wide SAF blending mandate directed at jet fuel suppliers had not yet come into force, but a patchwork of individual blending mandates had started to emerge across Europe (Use a Sustainable Aviation Fuels in Europe, 2022). The airlines also saw a notable technical risk in having access to SAF mix in the future, which could translate to further legal risk. Even without the threat of binding regulation, using SAF could mitigate customer expectations and reputation related pressures, much like compensation.

The use of SAF is thus driven and divided between regulatory compliance and voluntary action. For example, Norwegian fueled 517 tonnes of SAF under the Nordic blending mandates, and 7 tonnes through the voluntary market (CDP Worldwide, 2022f). Among the case airlines, voluntary SAF procurement was based on customers' voluntary action, airlines' voluntary purchases, or a mixture of the two. On the customer-side voluntary action, an airline offered its customers an option to purchase SAF fueling credits through a book and claim model, so the purchase credits were not necessarily fueled for a specific flight. The method is similar for corporate customers, for example, Neste supplied Finnair with 300 tons of SAF to reduce emissions from its employees' business travel (CDP Worldwide, 2022d). Airlines' own voluntary SAF purchases can be financed with a mandatory SAF fee, which typically ensures that the flight is fueled with a certain amount of SAF. From the beginning of 2022, AF-KLM advocated a mixed approach, where all planes flying out of Amsterdam would be fueled with 0.5% SAF, with a surcharge added to ticket prices, while individual and corporate

Table 3

The final framework on incumbents' responses to transition-related pressures. Response types marked with (e) were only supported by empirical evidence, and ones marked with (t) only by theoretical evidence.

1. SOCIO-CULTURAL STRATEGIES	
Thematic area	Responses
<b>Problem Framing</b>	<ul style="list-style-type: none"> <li>Use discursive actions to frame climate issues and solutions</li> <li>Participate in vision development</li> </ul>
<b>Stakeholder Engagement</b>	<ul style="list-style-type: none"> <li>Inform and engage with stakeholders</li> <li>Inform and engage with customers</li> <li>Advertise climate action to potential customers</li> </ul>
<b>Customer Behavior</b>	<ul style="list-style-type: none"> <li>Shape commonly agreed practices and norms</li> </ul>
2. POLITICAL STRATEGIES	
Thematic area	Responses
<b>Political Engagement</b>	<ul style="list-style-type: none"> <li>Lobby policymakers directly</li> <li>Lobby policymakers through organized pressure</li> </ul>
<b>Standard Development</b>	<ul style="list-style-type: none"> <li>Influence technical standard setting (e)</li> </ul>
<b>Confrontation</b>	<ul style="list-style-type: none"> <li>Threaten to re-organize operations</li> <li>Take legal action to oppose new regulation (t)</li> </ul>
3. INNOVATION STRATEGIES	
Thematic area	Responses
<b>Technical Changes</b>	<ul style="list-style-type: none"> <li>Make operative changes</li> <li>Make modular adjustments to existing technologies</li> <li>Adopt low-carbon technologies</li> </ul>
<b>Niche Innovations</b>	<ul style="list-style-type: none"> <li>Signal interest in niche innovations</li> <li>Create forward contracts for acquiring niche innovations (e)</li> <li>Investments in R&amp;D at the niches</li> <li>Form and take part in research partnerships</li> <li>Develop new infrastructure to accommodate niche innovations (e)</li> </ul>
4. ECONOMIC POSITIONING STRATEGIES	
Thematic area	Responses
<b>Value Chain</b>	<ul style="list-style-type: none"> <li>Change procurement practices</li> <li>Change waste management practices</li> </ul>
<b>Carbon Market</b>	<ul style="list-style-type: none"> <li>Purchase carbon offsets from the voluntary market</li> <li>Purchase carbon credits from the mandatory market</li> <li>Hedge emission credits (e)</li> </ul>
<b>Product &amp; Service Development</b>	<ul style="list-style-type: none"> <li>Offer add-ons or upgrades to old products/services</li> <li>Enter products/services into new markets (t)</li> <li>Introduce new products/services to the same market (t)</li> <li>Discontinue offering certain products/services (t)</li> </ul>
<b>Reorganization</b>	<ul style="list-style-type: none"> <li>Make practical changes to operations</li> <li>Outsource emission-intensive parts of operations (t)</li> <li>Transfer production to another country (t)</li> <li>Phase out technologies or practices in use</li> <li>Change business model (t)</li> </ul>

customers would still have the option to purchase additional SAF credits (CDP Worldwide, 2022a).

Airlines had a variety of ways to ramp up SAF production and to secure access at reasonable prices. Most had offtake agreements with SAF suppliers in place, committing to future purchases. Norwegian, Finnair, and EasyJet did not take this line, though Norwegian was actively seeking to establish offtake agreements. Such agreements were often accompanied by or a result of other forms of collaboration. AF-KLM, IAG, and Lufthansa had invested directly in SAF technology and production companies. For example, AF-KLM was a co-founder of SkyNRG, from which it had committed to purchase 75 000 tons of SAF annually for the following 10 years (CDP Worldwide, 2022a), while IAG had supported the development of the UK's first SAF production facility and started to receive SAF from the plant in 2022 (CDP Worldwide, 2022e). Ryanair appeared at that time to be the only airline with a strong SAF procurement plan based solely on purchase agreements with an external fuel supplier. An agreement with Neste included a promise to

power approximately a third of its flights out of Amsterdam Schiphol with a 40% SAF blend (CDP Worldwide, 2022g).

Responses targeted at fostering and enabling new transformative decarbonization solutions were common among the airlines. These would include cooperation schemes primarily based on knowledge exchange, such as Aviation Climate Taskforce, as well as research partnerships executed in collaboration with universities or other competence centers, or corporate partners from the value chain. However, there were multiple different technological solutions advocated by these research schemes. Finnair and Lufthansa have funded research on synthetic fuel production, AF-KLM on a complete redesign of an aircraft, EasyJet on development of a hydrogen engine, and IAG on the build-up of a hydrogen-electric aircraft. Diversification in R&D investment was clearly evident, signaling a lack of shared vision or knowledge on how to decarbonize aviation in practice. For example, only EasyJet and IAG had invested in hydrogen-based innovations, while Lufthansa has identified over 80 clean-tech projects together with its suppliers to reduce

emissions (CDP Worldwide, 2022b). Airlines were also signaling their interest in the development of certain technologies through official expressions of interest or letters of intent. For example, regarding next generation SAFs (Lufthansa), carbon capture and storage (EasyJet), hydrogen branch at the Paris airports (AF-KLM), and electric aviation (Finnair). Some airlines also reported taking responsibility in developing vital infrastructure and networks to support and enable upscaling of certain transformative technical solutions, such as SAF or hydrogen supply infrastructure. These types of response were centered around system level innovation.

Finally, not all of the airlines' lobbying and advocacy efforts were aligned. Notably, EasyJet reported its position in relation to A4E as 'mixed', whereas the other six airlines reported their position as 'consistent'. With EasyJet's influence, A4E has taken an increasingly neutral position on new climate-related regulation, rather than actively opposing it. EasyJet advocated for the SAF mandate and EU ETS to cover all flights departing from and landing in the EU, as opposed to the more common view that only intra-EU flights should be covered (CDP Worldwide, 2022c).

#### 4.2.3. Unconventional responses among the airlines

There was very little evidence of any action for a more radical change to core business components. Exceptionally, Lufthansa repeatedly mentioned intermodal transport as one of the key means through which to reach its climate targets. The airline collaborates with land-bound transportation operators to improve and integrate these services, in order to reduce the number of short-haul flights by offering alternative ways to travel and reach central transportation hubs. Fostering intermodality helps the company mitigate potential emerging regulation related to short-haul flights, as well as market and reputational risks related to rising concerns around sustainability of air-travel.

#### 4.3. Final pattern matching

The responses identified in the explorative twin theoretical and empirical investigation cover a wide range of different types of behaviors, which are presented in Table 3. The majority of the responses were supported by both organization and management literature as well as empirical evidence. However, the empirical findings also provided several new perspectives that could not be traced back to existing work, and there were also a few responses related to economic positioning strategies that were only found in the organization and management literature. These were still incorporated into the framework as they were deemed to present crucial response options that companies can utilize.

### 5. Discussion

#### 5.1. Conceptualizing incumbents' responses

The framework of incumbents' responses to transition-related external pressures developed through flexible pattern matching offers a new way for transition researchers to conceptualize incumbents' behavior in transitions. It adapts a more comprehensive and detailed view of the different types of responses that incumbents can engage in than earlier frameworks, inspired by the idea of seeing responses as specific activities as is common in organization and management literature. By taking a step back to this literature where the concept of response strategies was initially developed from and by adapting a strong firm-perspective, it managed to overcome some of the typical challenges related to developing new theoretical insight on incumbents' behavior, such as the abundance of different definitions, theories, analytical frameworks, and modes of interpretation (Kungl, 2024). The framework aspires to advance conceptual and analytical integrity related to incumbents' responses and inspire more differentiated research on the variety of activities that incumbents engage in to further explore their complex role in transitions.

However, the developed framework has probably merely scratched the surface of incumbents' responses to decarbonization, as it incorporated empirical findings only from one sector, and deliberately excluded responses related to internal operations, such as different managerial activities. The framework also did not consider insights that could have potentially been delivered from papers in transition literature that focus on specific areas of incumbents' behavior, due to challenges related to the ambiguity and plurality of this body of work. Nevertheless, reviewing this work and seeing how their findings could potentially populate the framework is an interesting research direction. For example, Apajalahti et al. identified that incumbents shape new technology fields by e.g., monitoring and donating money to develop niches, and forming internal R&D units (Apajalahti et al., 2018), whereas Smink et al., talk about technical standard development and distributing information as ways to obstruct niches (Smink et al., 2013), activities which would all align well with the proposed framework. This type of exercise could reveal how much research attention each response theme or type has received in transition literature, and probably also identify new response types in that process.

#### 5.2. Studying transitions in the making

There have been calls for developing new approaches to study incumbent organizations (Turnheim and Sovacool, 2020), and direct research efforts towards transitions in the making (Köhler et al., 2019). The transition risk lens adopted in this study illustrates a novel research approach for studying incumbents' behavior in these contemporary transition processes. Transition risk provided an extremely practical entry-point for investigating the low-carbon transition-related external pressures from incumbents' perspective, and the specific responses they employ to navigate this complex reality. By studying the responses that incumbents disclose for their stakeholders, primarily investors, it is possible to gain new insight on what these actors do when societies are decarbonizing.

The array of responses disclosed by the airlines in their CDP reporting was very broad and manifold, spanning various strategy and operational areas. It was clear that the airlines used this platform to try and convince their stakeholders about their excellence in dealing with climate issues, and that their businesses were aware of any transition developments that could influence their operations in the future. This ambition behind the disclosures conveys how the whole CDP reporting activity is actually a response to low-carbon transition in itself. Thus, not surprisingly, some airlines were much more direct than others about disclosing their responses to certain pressures, or what they were trying to achieve with specific responses in the first place. When utilizing the transition risk approach, one must therefore remain cautious of the primary purpose of these disclosures and whether all the information disclosed by the incumbents is fully transparent and truthful.

Distinguishing responses that are standard or unconventional among the incumbents, and the response areas where competing response logics emerged, were deemed central when analyzing the behavior on a regime-level. Although at first impression the responses might seem rather monolithic among all the incumbents, more detailed and critical investigation could uncover inconsistencies between them. As the case of the aviation sector illustrates, the transition risk approach can bring to light response areas with internal contestations and different viewpoints inside the regime. With this information, one can anticipate areas where central disputes are likely to arise and evaluate whether there are signs of weakening commitment based on response fragmentation. As each inconsistent response option can have different effects and consequences for the organizations themselves, transition, and the actual emission levels, this type of contemporary analysis can be useful for transition pathway analysis and perhaps even policy makers.

In this paper, the empirical investigation was conducted in a snapshot manner to direct research efforts towards discovering a wide range of different responses in detail. How incumbents' perceptions of external

pressures and responses develop over time would certainly be an interesting research direction to pursue in the future. Of course, this type of exercise might be restricted by the availability of information, as transition risk disclosure has only recently become a standard practice. However, the CDP database provides a lot of data that this study did not make use of. For example, information on the perceived severity and time horizons of the transition risks identified by the incumbents could be used to study the external pressures and individual responses more in detail. Future research could also evaluate not only the presence but the absence of the different kinds of responses, and the underlying factors behind the inconsistent and unconventional response strategies that build on the existing work on heterogeneous responses.

### 5.3. Responses as multifunctional and parallel entities

The empirical investigation of airlines' behavior revealed two important things about incumbents' responses to transition-related pressures. First, the findings showcase that incumbents' responses are often multifunctional, meaning that a response can target multiple different external pressures simultaneously. An example of this is airlines' varying carbon compensation practices, which purposes are to mitigate primarily market and reputation pressures related to customer and stakeholder perceptions and preventing legal action by civil society, whilst indirectly also influencing policy development. Second, responses can also appear parallel to one another. This refers to an observation that several responses can, and probably do, co-exist in relation to the same pressures.

These two response characteristics are in line with earlier studies on incumbents' behavior, which have acknowledged that firms can take part in different modes of behaviors simultaneously (Berggren et al., 2015; Geels and Penna, 2015; van Mossel et al., 2018). However, the precise characteristics of multifunctionality and parallelity have remained mostly implicit in this body of work. The investigation of the aviation sectors suggests that perhaps apprehending these characteristics more explicitly could support a more complex and nuanced understanding of incumbents' behavior in transitions.

## 6. Conclusion

This research has advanced the conceptualization of incumbents' behavior in transitions by developing a framework of different responses that these organizations might engage in to keep up with the decarbonization, based on a joint theoretical and empirical investigation. It also demonstrated a novel approach to studying incumbents' behavior in transitions in the making: utilizing incumbents' transition risk work. The empirical investigation of the aviation sector illustrated how even snapshot research can reveal the complex operating environment that the incumbents are navigating, and the variety of multifunctional and parallel responses they employ as a result. The transition risk lens provides an especially useful approach for detecting weakening commitment and potential regime fragmentation in contemporary transition processes, which can support future research endeavors in this complex domain.

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### CRedit authorship contribution statement

**Ella Tolonen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology,

Investigation, Formal analysis, Data curation, Conceptualization.

### Declaration of competing interest

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### Data availability

Data will be made available on request.

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