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The Difficulty of Climate Change Adaptation in Manufacturing Firms: Developing an Action-Theoretical Perspective on the Causality of Adaptive Inaction

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Abstract: Climate change induces various risks for supply chains of manufacturing firms. However, surveys have suggested that only a minority of firms conducts strategic adaptations, which we define as anticipatory and target-oriented action with the purpose of increasing resilience to climate change. While several barrier-centered studies have investigated the causality of non-adaptation in industry, the examined barriers are often not problem-specific. Furthermore, it has been shown that even in cases when managers perceive no barriers to adaptation at all, strategic adaptations may still not be conducted. On this background, the present analysis focuses on the logic of adaptive inaction, which we conceive, in particular, as inaction with regard to strategic adaptations. Adopting an action-theoretical perspective, the study examines (a) which aspects may shape the rationality of adaptive inaction among managers, (b) which more condensed challenges of conducting strategic adaptations emerge for managers, and (c) how the theoretical propositions can be tested. For this purpose, the study employs an exploratory approach. Thus, hypotheses on such aspects are explored, which may shape the rationality of adaptive inaction among managers. Subsequently, predictions are inferred from the theoretical propositions, which allow testing their empirical relevance. Methodologically, the hypotheses are explored by reexamining existing explanatory approaches from literature based on a set of pretheoretical assumptions, which include notions of bounded rationality. As a result, the study proposes 13 aspects which may constrain managers in conducting adaptations in such a way, which serves the economic utility of the firm. By condensing these aspects, 4 major challenges for managers are suggested: the challenges of (a) conducting long-term adaptations, of (b) conducting adaptations at an early point in time, of (c) conducting adaptations despite uncertain effects of the measures, and of (d) conducting adaptations despite cross-tier dependencies in supply chains. Finally, the study shows how the propositions can be tested and outlines a research agenda based on the developed theoretical suggestions.

Keywords: climate change; adaptation; manufacturing firms; strategic management; action theory

1. Introduction

Within research on climate adaptation in industry, adaptation has broadly been conceived as a question of economic self-interest of firms. Thus, it has been argued that climate change can induce various risks for firms, which arise from potential climatic impacts on the firm, on its supply chain network and on its political, economic and natural environment [1–5]. However, data from initial firm surveys on climate adaptation suggest that only a minority of managers is engaging their firms

in strategic adaptations [6–8], thus in ‘anticipatory and target-oriented action with the purpose of increasing resilience to climate change’ [7]. Such findings of a frequently occurring lack of strategic adaptations in industry have mostly been explained by lists of barriers to adaptation [3,4,9]. At the same time, a recent study has provided empirical evidence that even if managers do not perceive any barriers at all, strategic adaptations may still not be conducted [7]. Insights into problem-specific rationales of managers, which may explain such findings, yet have hardly been developed [7,10].

Based on this background, the present analysis examines the problem-specific logic of adaptive inaction, which will be defined as inaction with regard to strategic adaptations. Therefore, the study develops an action-theoretical perspective on the causality of adaptive inaction, which presumes utility-maximizing targets of managers and adopts notions of bounded rationality [11]. More specifically, the study examines (a) which aspects may shape the rationality of adaptive inaction among managers, (b) which more condensed challenges of conducting strategic adaptations emerge for managers, and (c) how the theoretical propositions can be tested. For this purpose, the study employs an exploratory approach. Thus, hypotheses on such aspects are explored, which may shape, in particular, the utility-oriented rationales behind adaptive inaction among managers. Subsequently, predictions are inferred from the theoretical propositions, which allow testing their empirical relevance. Methodologically, the hypotheses are explored by reexamining explanatory approaches from literature based on a set of pretheoretical assumptions.

While in reality, other forms of rationales, such as rationales shaped by values, emotions or habits [12], may similarly influence decisions of managers, the present study exclusively focuses on utility-oriented, instrumental rationales. Thus, the study only examines a part of reality, though one which is known to play an important role in strategic decision-making processes in firms [13] including such decision processes, which relate to climate adaptations [7].

In conceptual terms, the study applies the term agency restraints for designating those aspects, which shape the rationality of adaptive inaction. In particular, such agency restraints are explored, which may be faced by managers of manufacturing firms, as the latter have been conceived as being at risk of various potential impacts of climate change [1].

As an initial step, arguments underlining the importance of strategic adaptations in manufacturing firms are outlined. Afterwards, the state of research on the causality of adaptive inaction is depicted. Then, the applied model of action is described and its implications for employing the term agency are discussed. Subsequently, the employed exploratory approach is depicted. Thereafter, agency restraints are proposed and testable predictions are inferred. In a final discussion, the proposed agency restraints are condensed to more abstract challenges of conducting strategic adaptations, and next steps for analyzing climate adaptations in firms are suggested.

2. The Relevance of Strategic Adaptations for Manufacturing Firms

Various studies have so far examined climate risks for firms, which are linked to potential climatic impacts on firms, on their supply chain network and on their political, economic and natural environment [1,2,4,5,8,14–16]. Thus, it has been argued that climate change may influence businesses in various ways, for example by affecting the reliability of transportation or of water and energy supply, by affecting work productivity, or by inducing changes in political and economic framework conditions [1]. Referring to the discussed risks, it has been proposed that non-strategic forms of adaptations, such as ‘hidden adaptations’ [17,18] respectively adaptations by co-benefits [2,19] may not suffice, particularly if current emission trends persist, such as projected in the business-as-usual scenario of the IPCC (RCP8.5) [20]. With regard to strategic adaptations, various measures have been discussed. For example, adaptations which are supposed to increase the robustness of firms against direct (biophysical) impacts of climate change have been explored, such as proofing the built infrastructure of the firm against weather extremes [1,15,21,22]. Furthermore, adaptation options have been analyzed which may allow business resilience to indirect impacts of climate change, such as to climatic impacts on economic and political framework conditions. For example, resilience-increasing

product and management innovations have been discussed in this regard (for a broader overview of discussed adaptation measures, see [1,15,16,21,22]). However, management practices seem to predominantly contrast the suggested business relevance of climate risks as a minority of firms is currently implementing strategic adaptations, according to surveys [6,7].

3. The State of Research on the Causality of Adaptive Inaction

With regard to the causality of adaptive inaction, studies have predominantly examined barriers to adaptation, thus ‘factors and conditions which hamper the process of developing and implementing climate change adaptations’ [23]. A literature review, which summarizes the identified barriers to adaptation in industry, has been conducted elsewhere [7]. However, the barrier-centered perspective has recently been criticized as it would neglect actors, their strategies and motivation [7,10,23]. Furthermore, barrier-centered studies would tend to neglect the question *why* and *how* the barriers emerge [10,23]. Finally, some barriers, such as financial restrictions, would tend to be suggested regardless of the problem at hand [23]. The present study takes into account the depicted gaps by focusing on problem-specific aspects which may shape the rationales behind adaptive inaction.

Only in exceptional cases, studies have developed more theoretically condensed explanations of adaptive inaction. These exceptional studies have either employed sociological perspectives on communicative processes and discourses in municipal adaptation politics [10,24] or have examined the interplay of different psychological factors which can affect intention to adapt [7]. The mentioned studies especially allow understanding how perceptions relating to climate adaptations emerge as a consequence of psychological [7] or social [10,24] processes. However, these studies hardly provide general insights or predictions with regard to the behavior of actors within a particular population. The present study provides a first contribution to address this gap by developing propositions on utility-oriented rationales of managers and by inferring testable predictions on prerequisites of adaptations.

In literature, some scattered insights into utility-oriented rationales behind adaptive inaction can be detected. For example, rationales induced by the uncertainty of climatic developments have been analyzed [25–28] and possible strategies of risk reduction have been outlined [29]. Furthermore, some ideas on different time horizons of economically and climatically induced requirements of action have been suggested [27,30]. Finally, constraints for adaptations emerging from interdependencies between actors with diverging interests have been discussed [10,24,31].

The present study aims at systematically examining such utility-oriented aspects of choice with regard to climate adaptations. For this purpose, the study reviews explanatory approaches of adaptive inaction which have emerged in adaptation, sustainability and strategic management literature and reexamines the approaches based on simplifying assumptions about actors and their rationality.

4. Conceptual Foundations: The Employed Model of Action and Its Implications for Applying the Term Agency

In order to examine the logic of adaptive inaction among managers, the study employs a set of simplifying assumptions. In particular, it will be assumed that actors aim at utility-maximization, yet are restricted in this attempt due to incomplete information. The study thus adopts notions of bounded rationality [11], which have been widely applied in economic theory [13] and have also stimulated extensive experimental investigations [13].

Furthermore, it will be assumed that managers aim at maximizing the corporate utility of the firm. Though in reality, managers may also pursue personal ambitions [32], equating the interests of managers with the corporate interest of the firm has been considered as one way of approaching reality, at least when conceiving of managers as CEOs [33].

In addition, examining actor rationales implies a focus on a particular kind of non-adapting managers because rational action requires intention to act [12,34]. Therefore, the study conceives actors

as such managers, who intend to increase their firm's resilience, yet abstain from climate adaptations due to considerations of utility maximization.

Taking together the outlined assumptions, actors will thus be conceived as CEOs of manufacturing firms

- who intend to increase the resilience of their firms to climate change,
- who aim at maximizing the economic utility of the firm, and
- who are disposing of limited information.

Applying these assumptions, the study may contribute to existing debates on the causality of adaptive inaction in various ways. Thus, *by presuming the existence of intention to adapt*, the study may complement insights obtained from studies which have focused on causes for lacking intention to adapt [7,10,25,35,36]. Thus, the study may show that even if managers consider climate risks as a relevant business factor, strategic adaptations may still not be conducted due to various rationales. Furthermore, *assuming a utility-maximizing logic of action* may extend insights from barrier-centered analyses of non-adaptation (for reviews, see [7,23]) as removing barriers may foremost support adaptations if actors expect the adaptation to allow higher utility than inaction.

When examining the logic of adaptive inaction, the study especially focuses on the problem-specific aspects which shape this logic and terms these aspects *agency restraints*. Out of the various notions of agency, which have evolved in the social sciences (for an overview, see [37]), the study conceptualizes 'agency' closely attached to such notions of the term, which have been developed in rational choice theory [32,38,39], as the latter suit analyses of instrumental rationales. In this sense, *agency* will be defined as an actor's capability to choose deliberately between alternatives in order to pursue a specific target, while aiming at economic utility maximization. More specifically, *adaptive agency* will be defined as the respective capability to deliberately take adaptive action in order to increase resilience towards climate change, again given the assumption of instrumental rationality. Vice versa, *agency restraints* will be conceived as those aspects, which shape the rationality of inaction with regard to a particular problem by suggesting a higher utility of inaction than of action.

5. Outlining the Explorative Research Design

Due to the infant state of research into utility-oriented rationales behind adaptive inaction, an exploratory research design is applied. In particular, two steps of argumentation are taken. As a *first step*, hypotheses on agency restraints are explored. For this purpose, existing explanatory approaches from sustainability, adaptation and strategic management literature are reexamined from the outlined, action-theoretical perspective (see Section 4). In order to activate the invention of propositions on agency restraints [40], the literature review aimed, in particular, at discovering discrepancies between requirements and opportunities of conducting adaptations, which may be faced by managers, who aim at maximizing the economic utility of the firm. In order to detect such potential requirement-opportunity discrepancies, a combination of keyword and snowball research was applied in the literature review. Based on a discussion of each of the emerging requirement-opportunity discrepancies, agency restraints are proposed.

As a *second step* of argumentation, predictions are deductively inferred from each of the propositions on agency restraints. The predictions allow testing the empirical effects which the proposed agency restraints have on adaptation-related choices of managers [40].

It may be noted that conducting respective empirical tests represents the third step of argumentation within the iterated process of developing (falsifiable) theoretical explanations [40], yet rests beyond the scope of the present study.

In order to categorize the emerging agency restraints, the latter were assigned to three dimensions, thus 'bare aspects' [41], of the scrutinized problem in line with the topics emerging in the reviewed literature: the dimensions of time, knowledge and system boundaries, which are conceived as boundaries between actors in supply chain networks for the purpose of the present study. In the

following sections, potential agency restraints will be explored along these dimensions. An overview of the proposed agency restraints and of the inferred predictions will be provided in Section 7.

6. Emerging Agency Restraints along the Dimension of Time

Along the dimension of time, eight potential agency restraints were identified. The suggested agency restraints refer to two challenges of conducting adaptations, which may arise to managers: first, the challenge of conducting such adaptations, which may possibly yield benefits only in the long term (see Sections 6.1–6.4); and second, the challenge of conducting adaptations at an early point in time (see Section 6.5).

6.1. Managers' Adaptive Agency with Regard to Investment Horizons

Discussion of Requirements and Opportunities of Action

In order to become effective, some adaptations require long-term investment horizons. This may concern adaptations of the built infrastructure of the firm or such changes of the product portfolio, which require long innovation lead time, which is the time needed for research, development, distribution and product launch [42]. However, employing long-term investment horizons may often lack expectations of satisfying returns, particularly if high discount rates are assumed. In particular, discounting relates to the rationale that expectable future returns of investments decrease when losses are subtracted which occur over time. Such losses are typically conceived as opportunity costs, which are the missed returns from alternative investments, such as from investments at capital markets [43,44].

Proposition of Agency Restraints

In the described sense, the proposition (PRO) emerges that opportunity costs of lost returns from alternative investments constrain the agency of managers to engage their firms in long-term adaptations ($PRO_{Time(T)1}$).

Deduction of Predictions

The relevance which managers attribute to opportunity costs should decrease if the expected advantages of the investment increase. Thus, the prediction (PRE) follows that managers who ascribe a high business relevance to climate risks are more likely to engage their firms in long-term adaptations (PRE_{T1}).

6.2. Managers' Adaptive Agency with Regard to Long-Term Strategic Planning

Discussion of Requirements and Opportunities of Action

Applying long-term strategic planning horizons can be required for developing some adaptations, such as construction measures, some product innovations, or changes in long-term contracts. However, the utility of conducting long-term strategic planning can be questioned by several rationales.

One potential rationale refers to innovation lead time. In particular, short innovation lead time may question the utility of long-term strategic planning as flexible responses to changing demands are facilitated. In fact, only 10% of small and medium-sized companies (SMEs) have innovation lead times of more than 3 years and 28% have respective lead times of less than a year according to a survey among German SMEs [45], notwithstanding sectoral differences [42,46].

A second potential, adverse rationale concerns the lifespan of businesses. As only 50% of businesses survive the first five years of their existence [47], perceived risks of short-term mortality may question benefits of conducting long-term planning, in particular among managers of start-ups.

Proposition of Agency Restraints

Based on the outlined considerations, the proposition emerges that an uncertain value contribution of conducting long-term strategic planning restrains the agency of managers to engage their firms in long-term adaptations (PRO_{T2}).

Deduction of Predictions

The prediction follows that long-term adaptations become more likely if managers expect a higher value contribution of long-term strategic planning. In this sense, long-term adaptations should become more likely if managers

- consider long innovation lead time to prevail in their firm ($PRE_{T2.1}$) or
- have high confidence in experiencing a long lifespan of the firm ($PRE_{T2.2}$).

6.3. Managers' Adaptive Agency with Regard to Institutionalized Time Horizons

Discussion of Requirements and Opportunities of Action

Conducting long-term adaptations may also be disincentivized by institutions, which in line with a very short definition will be conceived as formal and informal rules [48]. Thus, mismatching institutionalized time horizons may decrease the utility of integrating long-term perspectives in corporate decision-making processes in various ways.

For example, *electoral cycles and related political variability* may question the utility of long-term adaptations due to uncertain future changes of framework conditions, such as potential future developments of emission trading, CO₂ taxes, or caps.

Furthermore, *annual or even quarterly reporting obligations* for companies at capital markets may incentivize the optimization of short-term instead of long-term business figures. Respective tendencies may moreover be supported by requirements regarding the *content of the reporting*. For example, companies at capital markets in the European Union (EU) are obliged to report on figures of the past business year but scarcely on future risks. Thus, in line with the EU directive on annual financial statements (Directive 2013/34/EU) or its national transposition laws, such as the German trade law (particularly §289 HGB), SMEs are not obliged to report on future risks. Even large listed companies are only obliged to disclose such environmental risks that represent relevant business information (§289 HGB). Notably, considerations of the 'relevance' of the respective information are subject to the discretion of the reporting company (§289 HGB). Moreover, reporting duties concern only such risks, which may become effective in a time horizon of 2–3 years in future in line with the interests of investors (International Financial Reporting Standards (IFRS) 7). The Corporate Social Responsibility Directive of the EU (Directive 2014/95/EU) similarly entails very limited duties of disclosing environmental risks as only such risks have to be reported, which are connected to high impacts *and* to high probability.

In addition, *time horizons imposed by informal institutions* might constrain long-term adaptations. This may include management customs, such as the focus of entrepreneurial crisis management on instant reactions to immediate crisis situations [2]. Similarly, routines of planners to extrapolate past data in forecasting models [42] may hardly provide the insights required for long-term adaptations to climate change as the latter is dynamic in nature [49].

Proposition of Agency Restraints

Based on these considerations, the following aspects are supposed to constrain the adaptive agency of managers:

- risks that adaptations induce sunk costs due to uncertain changes in political framework conditions (PRO_{T3}),
- uncertain value contribution of long-term adaptations due to the content of, and due to the time horizons imposed by, reporting legislations (PRO_{T4}), and

- enforcement costs of imposing a long-term orientation to informal institutions (PRO_{T5}).

Deduction of Predictions

Three predictions follow. Namely, that managers are more likely to engage their firms in long-term adaptations

- if they are aware of adaptation options whose effectiveness and efficiency is scarcely depending on political framework conditions (PRE_{T3}),
- if participating in voluntary reporting schemes, which incentivize the reporting of climate risks and adaptations, such as the Carbon Disclosure Project (PRE_{T4}), or
- if they are in charge of such companies, which already dispose of informal institutions oriented at long-term risk management (PRE_{T5}).

6.4. Managers' Adaptive Agency with Regard to Time Horizons Imposed by Significant Other Actors

Discussion of Requirements and Opportunities of Action

Furthermore, the expected utility of adapting to long-term risks can decrease if significant other actors impose short time horizons. For example, an average orientation of investment funds at profits at a horizon of less than 2 years has been suggested by figures of Morningstar. Thus, the average stock holding period by investment managers was 1.4 years across the 25 largest open-end mutual fund categories in 2013 [50]. Thus, allocating resources to the development of long-term resilience, and not to the maximization of short-term success, may induce risks of reduced attractiveness for some investors.

Proposition of Agency Restraints

Thus, the proposition emerges that risks of reduced attractiveness for some investors, such as investment funds, restrain the agency of managers to engage their firms in long-term adaptations (PRO_{T6}).

Deduction of predictions

The prediction follows that managers of family-owned firms or of firms financed by strategic investors are more likely to engage their firms in strategic adaptations than managers of firms financed by free-floating shares (PRE_{T6}).

6.5. Managers' Adaptive Agency with Regard to Early Mover Disadvantages

Discussion of Requirements and Opportunities of Action

As potential impacts of climate change may occur at an uncertain point of time in future, taking precaution may require early action. However, the expected utility of early action can be lower than that of waiting due to several rationales.

Such rationales may, for example, be shaped by the early state of political and economic developments in the field of climate adaptation [27,51]. For example, legal obligations for firms to disclose their climate risks have scarcely evolved so far (at least in the EU, see Section 6.3). Furthermore, such pressure on companies to adapt, which is emerging from financial markets, is only beginning to develop, notwithstanding first voluntary reporting initiatives referring to climate risks and adaptations, such as the Carbon Disclosure Project. In particular, legislative *obligations* for institutional investors to report on climate risks relating to their assets—which would induce subsequent pressure on companies to engage in adaptations—are lacking, notwithstanding one first approach in France [51]. As a consequence of these aspects, it can be assumed that early adaptations

of firms may be linked to lower effects on the attractiveness for investors and business partners than adaptations under more developed framework conditions.

Furthermore, early action in a field of high uncertainty and learning can raise concerns to miss future technological and scientific developments, which possibly allow a higher effectiveness and efficiency of the adaptation in question [52]. For example, such beneficial developments might include future access to improved 'climate services', thus to tools, products and information which support practitioners in dealing with climate change [53]. Thus, managers engaging their firms in strategic adaptations at present, may face risks of adjustment costs, which have been defined as costs incurred while learning about new climate conditions [52].

Proposition of Agency Restraints

On this background, the proposition emerges that the agency of managers to conduct strategic adaptations at an early point in time is constrained

- by efficiency risks of conducting adaptations under immature framework conditions (PRO_{T7}) and
- by risks of facing adjustment costs (PRO_{T8}).

Deduction of Predictions

The prediction follows that such managers are more likely to engage their firms in strategic adaptations

- who already perceive relevant business impacts of framework conditions, which relate to climate adaptations (PRE_{T7}), or
- who consider the available practical knowledge required for adaptations as sufficiently developed (PRE_{T8}).

7. Emerging Agency Restraints along the Dimension of Knowledge

Based on literature research, 2 potential agency restraints were identified along the dimension of knowledge. Both emerging agency restraints refer to the challenge of conducting adaptations despite discrepancies between required and feasibly achievable levels of knowledge.

7.1. Managers' Adaptive Agency with Regard to Risks of Negative Externalities

Discussion of Requirements and Opportunities of Action

Conducting adaptations in a utility-maximizing way requires the avoidance of negative externalities [27,29], which can sometimes be complex. For example, some adaptations, such as the installation of cooling systems, may increase CO₂ emissions. Furthermore, externalities of adaptations may induce negative social, ecological or economic developments in the supply chain network and its societal environment. For example, abandoning suppliers from climate-sensitive regions, such as vulnerable suppliers from arid or flood-prone areas, may increase the resilience of the supply chain but may worsen the vulnerability of these suppliers. In the same sense, developing 'green-tech' innovations, which may also be interpreted as adaptations to climatically induced shifts in demand, can induce side-effects, such as rebound effects [54] or the consumption of raw materials that are extracted in a socially or ecologically detrimental way. While such negative externalities of adaptations may induce reputational risks, their avoidance may in some cases surpass the informatory capacity of managers.

Proposed Agency Restraints

Thus, the proposition emerges that reputational risks of inducing negative externalities restrain the adaptive agency of managers (PRO_{Knowledge (K)1}).

Deduction of Predictions

The prediction follows that managers are more likely to engage their firms in strategic adaptations if

- estimating to dispose of high informational capacities ($PRE_{K1.1}$) or
- if estimating that the measure in question is connected to a low complexity and to a low severity of potential ecological, social and economic consequences ($PRE_{K1.2}$).

7.2. Managers' Adaptive Agency with Regard to Risks of Inducing Vulnerability-Increasing Lock-In Effects

Discussion of Requirements and Opportunities of Action

Discrepancies between required and achievable levels of knowledge may moreover induce risks of maladaptive lock-in effects that potentially decrease future resilience. Lock-in effects have been defined as constraining effects of decisions, events or outcomes at one point in time on options available at a later point in time [55]. For example, the installation of cooling systems may be costly to reverse if climate change requires stronger systems at a later point in time. Similarly, if innovations with long lead times are aiming at incremental changes, a strategy turn may be difficult if transformational innovations are instead required in future [56,57].

Proposed Agency Restraints

Thus, the proposition emerges that risks of inducing lock-in effects constrain the adaptive agency of managers (PRO_{K2}).

Deduction of Predictions

The prediction follows that managers are less likely to engage their firms in such adaptations, which presumably induce lock-in effects (for an overview of critical aspects, see [29]). Thus, such adaptations should become less likely to occur,

- which are connected to long-lived investments ($PRE_{K2.1}$) and
- which are only reversible at high costs ($PRE_{K2.2}$).

8. Emerging Agency Restraints along the Dimension of System Boundaries

Along the dimension of system boundaries, which are here conceived as boundaries between actors in supply chain networks (see Section 5), 3 potential agency restraints were discovered. The identified potential agency restraints all refer to the challenge of conducting strategic adaptations despite dependencies in supply chain networks.

8.1. Managers' Adaptive Agency with Regard to Cross-Tier Dependencies of Resilience-Increasing Innovations

Discussion of Requirements and Opportunities of Action

Increasing resilience based on product or management innovations may often depend on cross-tier cooperation in supply chains. At the same time, the influence that managers can exert on business partners can strongly vary, for example, depending on the power position which a firm holds within the respective chain. For example, a small furniture manufacturer intending to change to a more resilient type of wood may be hampered in this attempt if the furniture retailer rejects the product innovation supposing that his customers won't buy the new furniture. Similarly, management innovations aiming at increased resilience to climate change [1,15,16,21,22] can be hampered. For example, employing slack time in production processes in order to increase resilience can be inhibited if powerful customers demand the uninterrupted possibility of just-in-time delivery [1,58].

Proposed Agency Restraints

Subsequently, the proposition emerges that a low power position in the supply chain network constrains the agency of managers to initiate and develop resilience-increasing innovations across tiers (PRO_{System Boundaries (SB)1}).

Deduction of Predictions

The prediction follows that managers are more likely to engage their firms in cross-tier, resilience-increasing innovations if considering the position of their company within the supply chain as powerful (PRE_{SB1}).

8.2. Managers' Adaptive Agency with Regard to Cross-Tier Dependencies of Climate-Sensitive Risk Management

Discussion of Requirements and Opportunities of Action

An effective management of climate risks, too, can depend on cross-tier cooperation. Thus, it has been repeatedly argued that the effects of hazardous impacts of climate change can ripple throughout supply chains [1,4,5,8]. In fact, various options of developing cross-tier risk management exist, such as conducting risk audits among suppliers or supporting vulnerable suppliers in increasing their resilience [59–61]. However, opportunities to conduct such actions can be limited. For example, the power position in the supply chain can decide whether risk audits or the adoption of resilience-increasing measures can be imposed on suppliers [62] and risks reported by suppliers may not be controllable [63,64].

Proposed Agency Restraints

Subsequently, three potential agency restraints emerge:

- limitations due to having a low power position in the supply chain network (=PRO_{SB1}),
- costs of developing, introducing and enforcing a climate-sensitive management of cross-tier risks (PRO_{SB2}), and
- risks of trusting the information disclosed in cross-tier risk management (PRO_{SB3}).

Deduction of Predictions

The predictions follow that managers are more likely to engage their firms in cross-tier risk management

- if considering the position of their company within the supply chain as powerful (=PRE_{SB1}),
- if considering the company to be disposing of large (e.g., financial and personnel) capacities (PRE_{SB2.1}),
- if considering climate risks as highly relevant for business success (PRE_{SB2.2}), and
- if trust exists in business partners along the supply chain (PRE_{SB3}).

9. Discussion

The study has explored agency restraints for managers who aim at increasing the resilience of their firms to climate change. Table 1 summarizes the proposed agency restraints and the inferred, testable predictions. Furthermore, Table 1 condenses the proposed agency restraints to more abstract, major challenges of adaptations, which may be faced by managers.

Table 1. Condensed challenges, proposed agency restraints, and inferred predictions.

Challenges	Proposed Agency Restraints		Predicted Prerequisites for Adaptations	
Conducting long-term adaptations (T)	PRO _{T1}	Opportunity costs of lost returns from investments with shorter time horizons	PRE _{T1}	Consideration of climate risks as highly relevant for business success
	PRO _{T2}	Uncertain value contribution of long-term strategic planning	PRE _{T2.1} PRE _{T2.2}	Consideration that long innovation lead time prevails in the firm High confidence in a long lifespan of the firm
	PRO _{T3}	Risks that long-term adaptations induce sunk costs if changes in political framework conditions occur	PRE _{T3}	Awareness of adaptation options whose effectiveness and efficiency is scarcely depending on changing political framework conditions
	PRO _{T4}	Uncertain value contribution of conducting long-term adaptations due to the content of, and due to the time horizons imposed by, reporting legislations	PRE _{T4}	Situation of the firm to be participating in voluntary reporting schemes which incentivize the disclosure of climate risks
	PRO _{T5}	Enforcement costs of imposing a long-term orientation to informal institutions	PRE _{T5}	Situation of the firm to be already disposing of informal institutions oriented at long-term risk management
	PRO _{T6}	Risks of reduced attractiveness for some investors if allocating resources to optimizing long-term instead of short-term performance	PRE _{T6}	Situation of the firm to be family-owned or financed by strategic investors
Conducting adaptations at an early point in time (T)	PRO _{T7}	Efficiency risks of conducting adaptations under immature framework conditions	PRE _{T7}	Consideration of present framework conditions, which relate to adaptations, as already having a relevant impact on business success
	PRO _{T8}	Risks of facing future adjustment costs	PRE _{T8}	Consideration to dispose of sufficient practical knowledge on expectable climate impacts and on adaptation options
Conducting adaptations despite uncertain effects of the measure (K)	PRO _{K1}	Reputational risks of inducing negative externalities	PRE _{K1.1} PRE _{K1.2}	Consideration of the firm to dispose of high informational capacities Estimation that the respective measure is connected to a low complexity and low severity of ecological, social and economic consequences
	PRO _{K2}	Risks of inducing vulnerability-increasing lock-in effects	PRE _{K2.1} PRE _{K2.2}	Awareness of adaptation options which are not connected to long-lived investments Awareness of adaptation options which are reversible at low costs
	PRO _{SB1}	Constraints to conducting resilience-increasing innovations and cross-tier risk management in case of adverse actor constellations	PRE _{SB1}	Consideration of the company's position within the supply chain as powerful
	PRO _{SB2}	Costs of developing a climate-sensitive, cross-tier risk management	PRE _{SB2.1} PRE _{SB2.2}	Consideration that the firm disposes of large (e.g., financial and personnel) capacities Consideration of climate risks as highly relevant for business success
Conducting adaptations despite cross-tier dependencies in supply chains (SB)	PRO _{SB3}	Risks of trusting information disclosed in cross-tier risk management	PRE _{SB3}	Perception of trust in business partners

(T)/(K)/(SB): Challenge occurs along the dimension of time/knowledge/system boundaries.

As Table 1 shows, 13 potential agency restraints were detected, which can be condensed to 4 major challenges.

First, 6 agency restraints (see PRO_{T1} to PRO_{T6} in Table 1) can be subsumed under the major challenge of *conducting long-term adaptations*. In line with the content of the subsumed agency restraints, the challenge refers to difficulties of conducting such adaptations, which improve resilience in the long term, yet may not necessarily yield short-term benefits. At the same time, the results depicted in Table 1 suggest that adaptations may nonetheless occur, depending on considerations of managers with regard to firm characteristics (PRE_{T2.1/T2.2}; PRE_{T4} to PRE_{T6}), with regard to recognized adaptation options (PRE_{T3}) and with regard to the extent of perceived climate risks (PRE_{T1}).

Second, *conducting adaptations at an early point in time* emerged as a further major challenge. The challenge relates to aspects, which imply a higher utility of waiting than of conducting adaptations (see PRO_{T7} and PRO_{T8}). Again, Table 1 also proposes that the occurrence and the effects of this challenge are variable and may, in particular, depend on the state of developed political and economic framework conditions (see PRE_{T7}) as well as on the quality of already accessible, practical information (see PRE_{T8}).

Third, the emerging major challenge of *conducting adaptations despite uncertain effects of the measures* refers to discrepancies between the level of knowledge required for conducting specific adaptations and the level of knowledge achievable for managers, given limited informatory capacities (see PRO_{K1} and PRO_{K2}). However, Table 1 suggests that this challenge may lose its adverse effects on the implementation of strategic adaptations depending on considerations of managers with regard to adaptation options (PRE_{K1.2} to PRE_{K2.2}) and depending on firm characteristics (see PRE_{K1.1}).

As a fourth challenge, Table 1 suggests that *conducting adaptations despite cross-tier dependencies in supply chains* may impede strategic adaptations in manufacturing firms. Again, Table 1 suggests that the effects of this challenge are variable and may depend on actor constellations within the supply chain network (see PRE_{SB1}), on perceived trust in business partners (see PRE_{SB3}), on the expected impacts of climate change (see PRE_{SB2.2}), and on firm characteristics (see PRE_{SB2.1}).

However, as empirical tests are still lacking, the propositions on agency restraints as well as the condensed, major challenges still remain tentative. Therefore, future research may conduct statistical analyses which examine the empirical relevance respectively compare the effects of the proposed agency restraints on choices of managers relating to climate adaptations.

Depending on the results of such empirical tests, two basic directions emerge for further research. *First*, if tests falsify the propositions, new propositions may be invented, which allow explanations of adaptive inaction in firms. *Second*, if tests provide some evidence that the proposed agency restraints actually do affect strategic adaptations in firms, the following, subsequent questions emerge.

Thus, (a) empirically supported insights on agency restraints could be employed as given starting points for analyzing political and economic framework conditions in support of climate adaptations in firms. In this sense, it might be examined how framework conditions could be developed in a way, which is sensitive to the logic of action among managers and which could thus increase the effects of the respective policies on firm behavior.

In addition, (b) it could be analyzed how framework conditions can induce deeper changes in the logic of action by influencing the agency restraints themselves. For example, informatory framework conditions could be analyzed, which aim at an increased awareness of managers towards climate risks and at improved practical knowledge about adaptation options, as several agency restraints (as suggested in PRO_{T1}, PRO_{T3}, PRO_{T8}, PRO_{K2}, PRO_{SB2}; see Table 1) might be addressed in this way.

Limitations of the study especially refer to the employed pretheoretical assumptions. Thus, the rationales of managers may not only be shaped by the instrumental aim of maximizing the economic utility of the firm. Instead, rationales may also be shaped by value-oriented, affectual or traditional (i.e., habitual) rationality [12]. Furthermore, while intention to adapt is presumed in the present study, such intention can be questioned by various motivational factors as shown in existing, psychological adaptation studies [7,25]. In addition, differences in actor rationales may occur depending on the sector

because climate risks can vary between different manufacturing sectors [1]. Finally, social interactions may shape perceptions of climate risks and of adaptations among managers, and may subsequently influence the rationales.

10. Conclusions

Employing an action-theoretical perspective, the study has shown that despite considerable climate risks for manufacturing firms [1], various problem-specific aspects might make managers attribute a higher utility to inaction than to conducting strategic adaptations. In this regard, the study has suggested challenges of adaptations as well as conditions, under which the utility of conducting strategic adaptations may increase. However, empirical evidence of the propositions is still lacking. Generating such evidence might not only improve insights into the causality of adaptive inaction but may also promote the further analysis of framework conditions in support of climate adaptations in industry.

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