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Article — Published Version Decarbonization types of medium-sized and mid-cap firms in the manufacturing sector

Business Strategy and the Environment

Provided in Cooperation with: John Wiley & Sons

Suggested Citation: Block, Joern; Lorenzen, Solvej; Steinmetz, Holger (2024) : Decarbonization types of medium-sized and mid-cap firms in the manufacturing sector, Business Strategy and the Environment, ISSN 1099-0836, Wiley Periodicals, Inc., Hoboken, NJ, Vol. 33, Iss. 8, pp. 8833-8850, https://doi.org/10.1002/bse.3947

This Version is available at: https://hdl.handle.net/10419/313698

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RESEARCH ARTICLE

Revised: 29 June 2024



Decarbonization types of medium-sized and mid-cap firms in the manufacturing sector

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Abstract

The decarbonization of the manufacturing sector is needed to meet the climate goals set by the Paris agreement. Most research so far has focused on large firms. Yet, medium-sized and mid-cap firms also face increasing pressures to decarbonize, particularly in their role as suppliers of large firms. Prior research shows that these firms are very heterogeneous and that approaches to decarbonize are not adopted in isolation but within sets or configurations-hence, a detailed investigation of these configurations is fruitful to understand the multiplicity of responses to decarbonization. Such an understanding allows to develop an effective decarbonization policy for medium-sized and mid-cap firms and provide meaningful managerial advice. Using a latent-profile analysis, our study identifies five distinct decarbonization types of medium-sized firms in the German manufacturing sector that adopt a specific configuration of decarbonization strategies. These types can be described as decarbonization all-rounders, internal supply chain decarbonizers, total supply chain decarbonizers, decarbonization laggards and decarbonization sceptics. A comparison of these five decarbonization types reveals significant differences in stakeholder pressures, green capabilities and green innovation as well as firm performance and (structural) firm characteristics.

KEYWORDS

decarbonization, environmental sustainability, latent-profile analysis, manufacturing firms, medium-sized and mid-cap firms

INTRODUCTION 1

The decarbonization of the manufacturing sector is needed to meet the climate goals set by the Paris agreement. The manufacturing sector (excluding the energy sector) accounts worldwide for about 21% of

CO₂-emissions.¹ Sustainability regulations, such as the Corporate Sustainability Reporting Directive (CSRD)² or the EU taxonomy,³ increase the pressure for firms to develop and implement decarbonization

Abbreviations: AIC akaike information criterion: ANOVA analysis of variance: BIC bayesian information criterion: CATI, computer-assisted telephone interviews: CO2, carbon dioxide: CSRD, corporate sustainability reporting directive; EU, european union; NACE, Nomenclature Statistique des activités économiques dans la Communauté européenne; LPA, latent profile analysis: SME, small and medium-sized enterprises: STD, Standard Deviation.

¹See https://drawdown.org/drawdown-foundations (accessed 23 June 2024). ²The CSRD is a reporting directive aimed to enhance and standardize sustainability reporting requirements for listed firms operating within the European Union (European Commission, 2021 2022)

³The EU Taxonomy is a framework established by the European Union to classify economic activities based on their sustainability. It is a key part of the EU's Sustainable Finance Action Plan, aimed at promoting sustainable investments and financing the transition to a greener economy (European Commission, 2020).

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strategies. Although these regulations are currently focusing on large and listed firms, they also affect medium-sized and mid-cap firms (hereafter only medium-sized firms for reasons of readability) (European Commission, 2021, 2022; Schütze & Stede, 2021). Such firms are often indirectly affected in their role as suppliers of large firms (the so-called 'trickledown-effect⁴'). To maintain their position in the supply chain, they need to fulfil sustainability reporting obligations and provide corresponding proof of their sustainability and decarbonization performance (Ahern, 2023).

To date, however, our understanding of medium-sized firms' decarbonization strategies in the manufacturing sector is limited. This is a shortcoming, given the important role and impact of medium-sized manufacturing firms for many economies. For Germany, using the EU definition of small and medium-sized enterprises (SMEs),⁵ more than 98% of firms in the manufacturing sector belong to the group of SMEs (micro: 67.5%, small: 21.8%, medium: 7.9%).⁶ The manufacturing sector has both a strong economic and ecological impact. EU-wide, it accounts for 32.2% of the EU's value added and about 20% of CO₂emissions (Germany: 23%). These numbers underline the need to understand better the decarbonization approaches and actions taken by medium-sized manufacturing firms. Prior research shows that medium-sized are very heterogeneous and that approaches to decarbonize are not adopted in isolation but within sets or configurationshence, a detailed investigation of these configurations is fruitful to understand the multiplicity of responses to decarbonization. Such an understanding helps to develop an effective decarbonization policy for medium-sized and mid-cap firms and provide meaningful managerial advice.

Prior studies that analysed the configurations of firms' carbon reduction approaches and strategies mainly focus on the decarbonization of large and listed firms (Damert & Baumgartner, 2018; Furrer et al., 2012), particularly in high-polluting industries (Guo et al., 2023; Vieira et al., 2022). Yet, the knowledge gained from these studies cannot be transferred to the group of medium-sized firms as they differ from large firms in important aspects that can have an impact on decarbonization. Differences exist, for example, with regard to sustainability resources and capabilities (Dean et al., 1998; Hofmann et al., 2012), stakeholder relationships (Aguilera et al., 2007; Lähdesmäki et al., 2019) and management and ownership structures (Geeraerts, 1984; Zahra et al., 2000). Furthermore, it can be expected that-due to differences in the capabilities, competition strategies, industries and market environments-medium-sized firms strongly differ among each other in the patterns of different decarbonization strategies. For instance, some firms may adopt substantive decarbonization strategies focusing on internal processes due to specific sustainability and innovation capabilities while others focus more on symbolic strategies due to stakeholder pressure (Block et al., 2023).

Based on this rationale, we expect the overall population of mediumsized firms to consist of different decarbonization types with distinct decarbonization profiles. Our study thus aims to answer the following interrelated research questions: Which decarbonization types exist within the group of medium-sized manufacturing firms? Which firm characteristics are associated with these decarbonization types?

To answer these research questions, we conduct a latent-profile analysis (LPA) using information about the decarbonization efforts and strategies of a sample of 431 medium-sized German manufacturing firms. As profiling variables, we employ the importance that firms attach to internal and external CO_2 reduction as well as CO_2 compensation (also referred to as CO₂-offsetting). The analyses reveal five distinct decarbonization types: decarbonization all-rounders (23% of firms in our sample), internal supply chain decarbonizers (24%), total supply chain decarbonizers (19%), decarbonization laggards (28% of firms) and decarbonization sceptics (7%). A comparison of these five decarbonization types highlights significant differences in stakeholder pressures, green capabilities and green innovation, as well as firm performance and other (structural) firm characteristics. The most ambitious firms regarding decarbonization are found in the groups of decarbonization all-rounders and total supply chain decarbonizers. Firms with strong sustainability capabilities and experience are overrepresented in the groups of decarbonization all-rounders and total supply chain decarbonizers, where also the more economically successful firms can be found. In contrast, we did not find any significant differences regarding family ownership, firm age and firm size.

Our study contributes to several literature streams. First, we enrich the literature on firms' decarbonization strategies. Whereas previous studies on the configuration of decarbonization strategies mainly focus on large and listed firms (Vieira et al., 2022; Weinhofer & Hoffmann, 2010), the decarbonization of medium-sized firms is clearly under-researched. However, by constituting a substantial portion of the economy, their combined economic influence is substantial, making them important as players in the transformation towards a netzero economy (Koiral, 2019). At first glance, research shows only small differences between large- and medium-sized firms with regard to their decarbonization strategies (e.g., Furrer et al., 2012; Kolk & Pinkse, 2005; Weinhofer & Hoffmann, 2010). However, when analysing the predictors of medium-sized firms' decarbonization strategies, differences emerge. Previous studies on large firms found firms' ownership structures (Jeswani et al., 2008) and firm size (Damert & Baumgartner, 2018; Lee, 2012) being important predictors of decarbonization approaches. We cannot confirm this finding for our sample of medium-sized firms. In turn, we find that internal stakeholder pressure matters and is an important predictor of decarbonization approaches for medium-sized firms. This finding is somewhat in contrast to prior literature on the decarbonization of large firms, which finds only little influence of internal stakeholder pressure (Sprengel & Busch, 2011) or only in specific areas (Jeswani et al., 2008).

Our second contribution relates to a better understanding of the heterogeneity that exists regarding environmental sustainability *within* the group of medium-sized manufacturing firms. By analysing different predictors of decarbonization types, we enhance the literature on

⁴In this context, the 'trickledown-effect' describes the situation that large firms and banks pass on their reporting obligations to their suppliers being often small- and medium-sized firms.

⁵The EU defines SMEs as firms with fewer than 250 employees and less than 50 million in sales (or 43 million in balance sheet total).

⁶See https://www.ifm-bonn.org/statistiken/mittelstand-im-einzelnen/unternehmensbestand (accessed 23 June 2024).

medium-sized firms' environmental sustainability approaches (Bakos et al., 2020). Our findings highlight the degree and type of heterogeneity that exists within the group of medium-sized firms. Sustainability and innovation capabilities and stakeholder pressure put mediumsized firms on a more ambitious decarbonization path, whereas other factors such as family ownership, firm age and firm size have little or no effect. Thereby, our study adds to previous research on the influence of firm ownership regarding environmental sustainability (Ernst et al., 2022; Kariyapperuma & Collins, 2021; Lorenzen et al., 2024). Our study supports the findings of previous studies showing that the influence of family ownership on environmental sustainability should not be overestimated (Lorenzen et al., 2024) and can potentially be explained by differences in (sustainability) capabilities, experience and stakeholder influence (Dal Maso et al., 2020; Kariyapperuma & Collins, 2021; Williams & Schaefer, 2013). By displaying the higher importance of internal versus external stakeholder pressure regarding decarbonization, we further extend research on stakeholder proximity and its role in the environmental sustainability of medium-sized firms (Block et al., 2023; Ernst et al., 2022).

Finally, our findings also contribute to the discussion about symbolic and substantive sustainability strategies (Combs et al., 2023). By showing that a significant group of medium-sized firms pursue a strategy of substantive decarbonization, we cannot support the claims of Quintás and Martínez-Senra (2024) that medium-sized firms primarily seek symbolic legitimacy when engaging in decarbonization.

2 LITERATURE REVIEW

2.1 Environmental sustainability behaviour of medium-sized firms

By constituting a substantial portion of the economy, medium-sized firms are important drivers of sustainable practices. They collectively account for a large share of CO₂-emissions worldwide (Koiral, 2019), highlighting the need to understand their decarbonization strategies in detail (Isensee et al., 2020; Seidel et al., 2008). The group of medium-sized firms is highly heterogenous and so are their approaches towards environmental sustainability (Bakos et al., 2020). Prior research shows that their environmental sustainability behaviour varies depending on their resources and capabilities (García-Quevedo et al., 2020), ownership structure (Chu, 2011; Zhou, 2001) and stakeholder influence (Theyel & Hofmann, 2012). The specific characteristics of medium-sized firms can be both a barrier and a facilitator of environmental sustainability.

Prior research shows that medium-sized firms face specific financial and human resource constraints restricting them in their choice of environmental sustainability strategies (Garengo et al., 2005; Laforet & Tann, 2006; Woschke et al., 2017). The implementation of environmental strategies often involves high costs, risks and specific knowledge resources, which is why medium-sized firms are often more sceptical and slower compared to large firms to adapt their

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processes towards environmental sustainability (Rao & Drazin, 2002; van Burg et al., 2012).

On the positive side, prior research suggests that certain factors such as responsible and visible ownership (Villalonga, 2018), and close relationships with internal stakeholders (Block et al., 2023; Hyatt & Berente, 2017), in particular employees, constitute factors that facilitate positive environmental sustainability behaviour. Low hierarchies together with a strong alignment of management and ownership interests (Villalonga, 2018) can lead medium-sized firms to be very effective in their sustainability efforts. Moreover, the owners and managers of medium-sized firms are often closely connected to their stakeholders and visible in their local regional community, which can increase the stakeholder pressure on sustainability efforts. Through their embeddedness in the local community, medium-sized firms are shown to have a close connection to regional stakeholders (Lähdesmäki et al., 2019), which increases the effect of stakeholder pressure to implement substantial environmental sustainability strategies (Ernst et al., 2022). Moreover, medium-sized firms often have a good access to specific resources from their network, which facilitates strategy implementation. Family-owned firms, which is an important sub-group of medium-sized firms, have been shown to adopt environmental sustainability practices based on their emotional attachment to the firm (Nikolakis et al., 2022), their aim to build and maintain a positive reputation, and their long-term and intense stakeholder relationships (Le Breton-Miller & Miller, 2006). Prior studies also show that managers' commitment to environmental sustainability (Bakos et al., 2020), their goals and values (Jansson et al., 2017) and their education and experience (Khattak et al., 2023) are important drivers of the implementation of environmental sustainability initiatives. These managerial effects are arguably larger for medium-sized than for large firms.

2.2 Corporate decarbonization strategies

Decarbonization is defined as the process by which countries, individuals or other entities aim to reduce their CO₂-emissions by changing the creation or use of energy as well as transforming the (energyand/or pollution-intensive) industry and transport sectors (IPCC, 2018). Corporate decarbonization strategies can be understood as those strategies that firms apply to reduce or eliminate their CO2emissions to achieve net-zero emissions. Participating in decarbonization efforts has become a strategic requirement for firms. Yet, along with combating climate change and helping to safeguard the environment, decarbonization also entails business opportunities, such as the creation of green product innovations, and helps firms staying competitive in a shifting global market.

Corporate decarbonization strategies encompass a collection of actions designed to diminish or reduce the CO2-emissions produced by a firm. According to Johnson et al. (2023), the spectrum of concrete decarbonization actions is broad, comprising administrative actions (e.g., target setting and adoption of environmental management systems), applicative actions (e.g., process improvement, or

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product innovation for low-carbon products and energy efficiency), communicative actions (e.g., reporting or public relations) or collaborative actions (e.g., supply chain coordination, carbon trading, or carbon offsetting). Different drivers on various institutional, organizational and individual levels exist (Johnson et al., 2023).

Prior studies have found that decarbonization actions of mediumsized firms are rather heterogeneous and vary in their scale and scope (e.g., Boiral, 2006; Luderer et al., 2019; Weinhofer & Hoffmann, 2010). Examples include carbon management activities such as emission reduction commitment or process and supply improvement (Damert & Baumgartner, 2018; Lee, 2012), the actual reduction of greenhouse gas (GHG) emissions (Sprengel & Busch, 2011), CO₂-emission management strategies such as CO₂compensation or CO₂-reduction (Weinhofer & Hoffmann, 2010) or climate change strategies such as process improvement or product development (Kolk & Pinkse, 2005).

2.3 | Prior research on decarbonization of medium-sized firms

To date, only few studies have focused on the topic of decarbonization of medium-sized firms as well as their specific decarbonization strategies. Gomes and Pinho (2023), for example, examine the overall contribution of SMEs to CO₂-neutrality and their role in achieving the global sustainability targets. They demonstrate that the implementation of resource-efficient actions at the micro level, such as optimizing energy use in production processes and reducing waste through recycling, has a positive influence on the adoption of decarbonization measures on the macro-level (in this case: the level of the firm). This effect was found to be enhanced by business investment activities. Nevertheless, their results also indicate that there is still a significant amount of progress to be made by SMEs in order to achieve global sustainability targets. In particular, external regulations and financial requirements could act as a barrier to the implementation of the necessary CO₂-reduction practices. Other studies focused on the specific drivers of decarbonization in SMEs. Block et al. (2023), for example, found that the perceived stakeholder pressure shapes medium-sized firms' decarbonization attempts. Whereas internal stakeholder pressures lead to increased reliance on substantive decarbonization strategies, the pressure from external stakeholders is associated with the implementation of both, substantive and symbolic decarbonization strategies. Additionally, the type of firm ownership seems to play a role, with differences observed between familyand nonfamily-owned firms. The authors could show that family ownership weakens the impact of external stakeholder pressure on symbolic decarbonization strategies. Zhou and Zhao (2016) and Shaik et al. (2024) highlight the role of strategic and technological drivers in reducing CO₂-emissions in SMEs. Specifically, focusing on coal consumption and coal production CO₂-emissions, the study of Zhou and Zhao (2016) indicates that technological innovations help SMEs in reducing pollutant emissions and thus are a key factor in SME's environmental improvement. Shaik et al. (2024) tested the effect of artificial

intelligence (AI) in creating sustainable business models. The authors demonstrate that the use of technological enablers, such as AI-driven business models, allows SMEs to optimize their operations and align resource management with sustainable practices, which drives their sustainable transformation towards low-carbon businesses. The study of Jiang et al. (2023) focused on the role of integrating CO₂-reduction objectives in SMEs in China. Emphasizing the significance of evaluating and selecting appropriate strategies for integrating environmental, social and governance (ESG) practices and natural resource management in SMEs, they identified key strategies for achieving these targets. These strategies include eco-friendly packaging, sustainable transportation practices and the establishment of carbon reduction targets. Integrating these carbon reduction objectives could enable SMEs to contribute to environmental sustainability and facilitate the development of a resilient and sustainable economy. Focussing on CO₂-offsetting, Triana and Ota (2024) investigated the preferences for forest carbon credit offsets of SMEs in Japan. They find that SMEs held a neutral stance regarding offsetting and were still in the early stages of engagement with carbon offsetting. Yet, they were willing to pay a higher price for carbon credits from local versus overseas projects.

2.4 Previous research on decarbonization types

Prior studies have analysed the configurations of firms' specific decarbonization strategies. Yet, the majority of these studies have focused on large- or mixed-firm samples in a variety of industry sectors. Weinhofer and Hoffmann (2010) analysed firms' configurations of CO₂emission management strategies in the electronics sector. The authors proposed five distinct clusters and analysed differences between those clusters in their regional affiliation, firm size and absolute versus relative CO₂-emissions. Their results show that the majority of firms focused on long-term emission management strategies and that their CO₂-strategies are mainly influenced by firm size, regional differences and their total emissions produced. Damert and Baumgartner (2018) used a similar approach but widened their sample to (automotive) firms in Japan and South Korea, the EU, the United States and Canada. Based on a sample of 116 firms surveyed for the Carbon Disclosure Project (CDP) and a content analysis of company documents, they clustered firms' carbon reduction approaches according to four strategic intents. Differences between the clusters have been analysed based on additional factors, such as the firm's supply chain position, firm size, firm performance and the institutional environment. Next to a positive influence of firm size on firms' carbon reduction attempts, the authors also show significant differences in climate change strategies based on firms' position in the production process. Furrer et al. (2012) add to these findings by analysing the climate change activities of firms in the banking sector. Differentiating between symbolic and substantive climate change activities, they could show that few of the firms implement solely symbolic decarbonization strategies, but that the majority of firms engage in both symbolic and (long-term) substantive strategies.

Other studies applied a cross-industry analysis, either using samples of single or mixed countries, or a worldwide analysis. Sprengel and Busch (2011), for example, assessed how the selection of an environmental strategy is influenced by various external factors. Based on survey data of firms from eight GHG-intensive industries, they analysed firms' strategies applied to reduce their GHG emissions. They show that the level of pollution had the highest influence on firms' environmental strategy whereas they could not find any influence of specific stakeholder groups. Lee (2012) focused his analysis on energy-intensive, general service/manufacturing, and specialized sectors in Korea. He grouped firms' carbon management activities, such as Emission Reduction Commitment or Process & Supply Improvement. Analysing different drivers of firms' decarbonization strategy, his findings indicate a significant influence of industrial sector and firm size.

Table S1 summarizes previous research on decarbonization types and configurations.

3 | DATA AND METHOD

3.1 | Dataset and survey

Our sample was collected in two steps. The initial sample was collected based on the Orbis database from Bureau van Dijk that provided data on firm characteristics, such as ownership data or performance measures. To be included in the initial sample, a firm needed to meet the following criteria: (1) The firm was active in September 2020; (2) the firm was located in Germany; (3) its primary nomenclature statistique des activités économiques dans la Communauté européenne (NACE) code was between NACE 20 and NACE 30; (4) the number of employees was between 50 and 2999; (5) it was at least 10 years old; and (6) it was not a subsidiary, a foreign firm, a non-profit firm or a listed firm. This sampling scheme allowed us to capture a broad spectrum of emission-intensive manufacturing industries and exclude start-ups and young firms. We decided to exclude start-ups and young firms as previous research suggests that they differ from established medium-sized enterprises in important aspects that are relevant for our research goals (Krishnan et al., 2020). Most importantly, they may not be mature enough and may not have established business models with clearly defined products and customers. In such a situation, decarbonization is not needed in the first place. Hence, our focus is on established, medium-sized firms. Applying these steps leaves us with an initial sample of 10,765 medium-sized and mid-cap manufacturing firms.

In a second step, we contacted 1959 firms randomly chosen from our initial sample to participate in a survey. The survey was conducted by a German empirical social research institute between January and April 2022 in the form of computer-assisted telephone interviews (CATI), addressing respondents from the first or second management level of the respective firm. These persons were identified by a research associate of our team to ensure valid responses based on solid insights into the corporate and sustainability strategy of the firm.

Prior to the main survey, we conducted extensive pre-tests with industry experts to secure the comprehensibility of the survey questions. As a result, the survey questions were formulated in a simple and understandable way. The result was a detailed script for the interviewers that included the provision of explanatory texts, read out by the interviewers in case of further inquiry. Incentives were provided to the interviewees to encourage accurate and detailed responses, including a customized management summary for the firm and an invitation to a workshop on the survey results designed exclusively for the survey participants. Additionally, respondents were informed that their data would be processed anonymously and for scientific purposes only. The survey questions were presented in a manner that would not allow for a direct identification of a relationship between the constructs. Social desirability bias, in particular, was addressed by including a commitment measure in the survey and applying a linear regression analysis using the commitment measure as dependent variable.

From 1959 firms contacted, 444 responded and took part in the survey, resulting in a response rate of 22.66%. Further checks to control and reduce potential sample biases were conducted. These checks include a check for non-response bias⁷ as well as late response bias.⁸ After completion of the survey, the data were processed and merged with firm-level data from the Orbis database. Cleaning the data and removing missing values led to a final sample of 431 firms.

3.2 | Measures

3.2.1 | Decarbonization strategies

The survey questions were developed based on the sustainability literature and expert interviews. The questionnaire included singlechoice, multiple-choice and ranking questions, focusing on decarbonization, environmental and quality management, EU taxonomy, family business, firm characteristics and human capital of the respondent. The survey measures for decarbonization strategies were based on a generic perspective and differentiated between internal and external CO_2 -reduction and CO_2 -compensation strategies (Cadez et al., 2019). This differentiation allows us to distinguish between different strategic priorities of the firm (Cadez et al., 2019).

With internal decarbonization strategies, firms put their focus on the internal reduction of CO_2 emissions. Participants were therefore asked to indicate the importance of internal CO_2 -reduction strategies for their firm on a 5-point rating scale ranging from 1 (*not important*) to 5 (*very important*). Internal decarbonization strategies focus on the reduction of the firm's Scope 1 emissions (Cadez et al., 2019).

⁷To control for non-response bias, the characteristics of the 1959 firms that were contacted for the survey and the 443 that took part were compared. The respondents were significantly larger in terms of number of employees compared to the non-respondents. However, the two groups did not differ in terms of industry sector and location. ⁸Due to the sampling in the time of the Russian war against Ukraine, starting in the beginning of 2023, the sample was divided into two groups of early and late respondents. We compared the distribution of the three dependent variables, but no differences in the dependent variables can be observed between the two groups.

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Relevant examples include the reduction of firms' process emissions in the production. Within previous literature, internal decarbonization strategies refer to strategies such as CO_2 reduction (Weinhofer & Hoffmann, 2010) or CO_2 -mitigation (Vieira et al., 2022) and include carbon management activities such as process improvement (Kolk & Pinske, 2005), internal climate change activities (Jeswani et al., 2008), product improvement (Lee, 2012), combustion emissions reduction, process emissions reduction or lowering product output (Cadez et al., 2019).

External decarbonization strategies are linked to the reduction of firms' total supply chain emissions. Participants were thus asked to indicate the importance of external CO_2 -reduction strategies for their firm on a 5-point rating scale ranging from 1 (*not important*) to 5 (*very important*). External decarbonization strategies focus on the reduction of both Scope 2 and Scope 3 emissions and comprise firms' activities to reduce CO_2 -emissions along the entire supply chain (Cadez et al., 2019). Prior literature refers to external decarbonization strategies as the strategy of CO_2 -independence (Vieira et al., 2022; Weinhofer & Hoffmann, 2010) and includes climate change management activities such as process and supply improvement, new market and business development (Lee, 2012) or supply chain emission reduction (Cadez et al., 2019).

 CO_2 -compensation strategies are measured as the priority that firms place on acquiring voluntary CO_2 -certificates to offset or balance their negative environmental footprint (Cadez et al., 2019). Participants were asked to indicate the importance of CO_2 -compensation strategies in their firm on a 5-point rating scale ranging from 1 (*not important*) to 5 (*very important*). Within previous literature, this strategy relates to CO_2 -compensation (Weinhofer & Hoffmann, 2010) and includes strategic activities such as acquisition of emission credits (Kolk & Pinske, 2005) or emission trading (Cadez et al., 2019).

In line with previous studies, internal and external decarbonization strategies can be regarded as substantive environmental strategies, as they are long-term oriented, focus on actual CO₂ reduction and assign a high priority to environmental criteria in a firm's decisionmaking (Hyatt & Berente, 2017). CO₂-compensation strategies, in turn, can be considered symbolic, as they do not necessarily enhance firms' environmental performance but rather aim to protect a firms' reputation (e.g., Hyatt & Berente, 2017; Rodrigue et al., 2013).

3.2.2 | Predictors of decarbonization types

To analyse differences within the group of medium-sized firms, we classify potential predictors of firms' decarbonization strategies into four overarching groups of predictors: (1) stakeholder pressure and stakeholder legitimacy, (2) green capabilities and green innovation, (3) decarbonization ambitions and (4) structural firm and industry characteristics. We chose these predictors based on their importance displayed in previous research as we explain below.

Stakeholder pressure and stakeholder legitimacy evaluate stakeholders' ability to influence firms' organizational decisions and the (own) perception of firms to operate in an ecologically responsible manner (Fassin, 2009; Helmig et al., 2016; Kassini & Vafeas, 2006). We differentiate between internal and external stakeholder pressure and whether firms aim for a green image or green reputation.

Green capabilities and green innovation refer to the specific capabilities and resources that enable a firm to operate in an environmentally sustainable way. More specifically, we measure the implementation of environmental management systems, the implementation of emission reduction measures and the use of green certifications. We also summarize all these measures in an environmental professionalism index. Finally, we also account for the capability of the firm to produce green innovations and thereby distinguish between different objects of innovation (e.g., product innovation, business model innovation and service innovation).

Decarbonization ambitions refer to firms' decarbonization goals and milestones to reduce their CO_2 -emissions. These include medium-sized firms' priorities to reduce their CO_2 -emissions and the actual CO_2 -reductions achieved. To measure firms' decarbonization ambitions, we ask participants to indicate their firms' priority of CO_2 reduction, their firms' priority of CO_2 -reduction along the entire supply chain and their firms' actual CO_2 -reduction over the last 5 years.

Structural firm and industry characteristics contain a diverse set of firm, industry and market factors that distinguish one firm from another. Structural firm characteristics comprise the number of employees of the firm, firm age, family ownership and whether the firm operates in a B2B or B2C market. We further account for firm performance and strategy variables as predictors. These variables comprise growth ambition, profitability, sales growth, niche versus broad market coverage, the specific competition strategy employed (cost focus, guality focus and innovation focus) and the level of production depth. Regarding industry characteristics, we account for different NACE 2 sectors, that is, chemicals and chemical products, pharmaceutical products, rubber and plastic products, non-metallic mineral products, basic metals, fabricated metal products, computer, electronic and optical products, electrical equipment, machinery and equipment, motor vehicles, trailers and semi-trailers and other transport equipment sectors.

Table S2 gives a detailed overview of the variables and their respective measurement.

3.3 | Analytical procedure

We apply a latent profile analysis (LPA) to identify latent classes of firms with similar decarbonization strategies. A LPA is a statistical method for identifying related cases from multivariate continuous data (Bauer & Curran, 2004; Lanza & Cooper, 2016). Unlike traditional cluster analysis that is rooted in identifying similar profiles of observed variables, a LPA applies a latent variable framework and attempts to identify a latent categorical variable with each level referring to unobserved latent populations. In doing so, a LPA is similar to the latent class analysis with the difference that the *class indicators* (i.e., the observed variables that reflect class membership) are continuous whereas a latent class analysis uses binary indicators. Both

approaches belong to the overall class of finite mixture models (McLachlan & Peel, 2000), whose basic premise is that the data (i.e., the multivariate probability distribution of the observed indicators) were generated by a mixture of underlying distinct subpopulations.

We ran a series of LPA models differing in the number of latent classes ranging from 3 to 8. Inspected evaluation criteria were the Akaike information criterion (AIC), corrected AIC (CAIC), Bayesian Information Criterion (BIC), entropy (Celeux & Soromenho, 1996), which reflects the (un)certainty when assigning cases to the referring class, and the minimal and maximum average posterior probability of the class assignment ($Pr(class = c \mid individual = i)$). A reasonable model should have the lowest AIC. CAIC and BIC values among comparable models with different numbers of classes and the highest entropy and posterior probability values. More importantly, however, is the theoretical appropriateness and interpretability of the classes' meaning. The analysis was conducted with the tidyLPA package from R (Rosenberg et al., 2018). Other used R-packages were dplyr for data wrangling procedures and ggplot2 for visualization (Wickham et al., 2022).

4 RESULTS

4.1 **Descriptive statistics**

The firms in our sample have a mean of 49 years (median: 39 years) and 302 employees (median: 167 employees). The oldest firm in our sample is 208 years old; the youngest firm has an age of 12 years. The majority of firms in our sample operate in the machinery industry (25%), followed by the metal industry (21%) and the rubber and plastic industry (13%). Seventy percent of firms operate in the B2B sector, 49% of the firms are family firms. Eighty-six percent of the firms in our sample have between 50 and 499 employees; 14% have between 500 and 2999 employees (so-called mid-caps, Röhl. 2018).

Firms in our sample consider internal decarbonization strategies as the most important decarbonization strategy (mean = 4.15, std. dev. = 0.94), followed by external CO_2 -reduction (mean = 3.46, std. dev. = 0.99) and CO₂-compensation (mean = 2.57, std. dev. = 1.29). These results indicate that firms in our sample apply more substantive rather than symbolic decarbonization attempts and focus on a long-term oriented decarbonization of their supply chain rather than offsetting their CO₂-emissions by (voluntary) CO₂-certificates over the short term. Still, there exists a large variance in the decarbonization strategies employed, which is what our study aims to explore.

With regard to the overall business strategy, firms in our sample have high growth ambitions (mean = 3.49, std. dev. = 1.08) and mainly follow a quality focus strategy (mean = 4.20, std. dev. = 0.75) rather than a cost focus strategy (mean = 3.23, std. dev. = 0.98). Regarding green image, firms consider their green credibility to be an important factor. Many firms have an environmental management system (73%). They also implement green innovation (mean = 1.80, std.

dev. = 0.44) with a focus on green production and process innovations (mean = 2.13, std. dev. = 0.62) and less on green product innovations (mean = 1.87, std. dev. = 0.71).

4.2 **Results of the LPA**

The information criteria (AIC, BIC and CAIC) support an eight-class solution of the LPA. In contrast, the entropy measure and estimates of the minimal and maximal probability clearly indicate a solution with five groups. This solution also deemed the most interpretable one. To interpret the characteristics of the groups, we focus on the mean values of the three decarbonization strategies, that is, internal CO₂reduction, external CO2-reduction and CO2-compensation. The results of the LPA and the resulting five decarbonization types are presented in Table 1. In a next step, these decarbonization types are profiled according to decarbonization ambitions, stakeholder pressures and legitimacy, green capabilities and green innovation, (structural) firm characteristics and firm performance and strategy. Such a profiling allows us to identify how the decarbonization types differ from each other. We display the mean values of the profiling variables in each group and apply statistical mean and proportion comparisons to test whether the decarbonization types differ along the profiling variables.

Description of identified 43 decarbonization types

4.3.1 Decarbonization all-rounders

Decarbonization all-rounders consider the complexity of decarbonization and score high on each specific decarbonization strategy. We found that 99 firms (23%) in our sample belong to this group. Firms in this group place high importance on CO₂-reduction through internal (mean = 5.0) and external decarbonization strategies (mean = 4.05)and also engage in CO_2 -compensation (mean = 3.79). Decarbonization all-rounders resemble the 'all-rounders' (Weinhofer & Hoffmann. 2010). 'all-round-enhancers' (Damert & Baumgartner, 2018; Lee, 2012) and 'emission avoiders' (Sprengel & Busch, 2011) identified in prior studies.

4.3.2 Internal supply chain decarbonizers

Firms in the group of internal supply chain decarbonizers focus on the decarbonization of their internal supply chain. They place a high importance on internal decarbonization strategies (mean = 3.74) rather than on external decarbonization (mean = 3.0) and CO_2 compensation (mean = 1.39). This decarbonization type has been described in prior research as 'internal explorer' (Kolk & Pinkse, 2005). One hundred five firms (24%) of our sample belong to this group.

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TABLE 1	Decarbonization types a	as a result of the	latent-profile analysis.
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	Name and descript	ion of decarbonization	on type			
Decarbonization strategy	Decarbonization all-rounders (implementation of all decarbonization strategies)	Internal supply chain decarbonizers (focus on internal decarbonization)	Total supply chain decarbonizers (focus on both internal and external decarbonization; no CO ₂ -compensation)	Decarbonization laggards (stuck in the middle)	Decarbonization sceptics (little decarbonization efforts across all three strategies)	χ ² -Kruskal– Wallis test (p- value)
Internal decarbonization strategy	5.00	3.74	5.00	3.85	1.64	339.22 (p = .000)
External decarbonization strategy	4.05	3.00	3.50	3.56	2.71	66.40 (<i>p</i> = .000)
CO ₂ - compensation strategy	3.79	1.37	1.50	3.55	1.79	310.27 (p = .000)
Ν	99	105	80	119	28	
Percentage of firms (%)	23.0	24.4	18.6	27.6	6.5	

4.3.3 | Total supply chain decarbonizers

Total supply chain decarbonizers focus on the decarbonization of the overall supply chain and avoid CO_2 -compensation. Hence, total supply chain decarbonizers consider internal decarbonization strategies (mean = 5.0) and external decarbonization strategies (mean = 3.50) as the most important decarbonization strategies and place less importance on CO_2 -compensation (mean = 1.50). This decarbonization type resembles 'vertical explorers' (Kolk & Pinkse, 2005) and reducers (Lee, 2012) identified in prior research. Eighty firms (19%) of our sample belong to this group.

4.3.4 | Decarbonization laggards

Decarbonization laggards have no clear decarbonization strategy. They are stuck in the middle between internal decarbonization strategies (mean = 3.85), external decarbonization strategies (mean = 3.56) and CO_2 -compensation (mean = 3.55). With 119 firms (28%), this group represents the largest group in our sample and is similar to the strategy types 'cautious reducer' (Lee, 2012) or 'beginner' (Jeswani et al., 2008) identified in previous research.

4.3.5 | Decarbonization sceptics

Decarbonization sceptics do not place importance on any of the decarbonization strategies, neither on internal decarbonization strategies (mean = 1.64), external decarbonization strategies (mean = 2.71) nor on CO₂-compensation (mean = 1.79). With 28 firms (7% of the sample), the number of firms in this group is relatively low. Firms in this group resemble the types of 'wait and see observer' (Lee, 2012),

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'preserver' (Weinhofer & Hoffmann, 2010) or 'cautious planner' (Kolk & Pinkse, 2005) identified in prior research.

4.4 | Predictors of decarbonization types

Differences across the five identified decarbonization types are displayed in Tables 2–4. For the correspondence analysis between decarbonization profiles and the predictors, different statistical tests were carried out. We applied an ANOVA to test whether the differences in continuous variables are statistically significant across the different decarbonization types. For binary and ordinal categorical variables, we used a χ^2 -test to examine differences between the groups.

4.4.1 | Stakeholder pressure and stakeholder legitimacy

Stakeholder pressure is above average in the group of *decarbonization all-rounders* (mean = 2.78) and *total supply chain decarbonizers* (mean = 2.44), and below average in the other groups, such as in the group of *internal supply chain decarbonizers* (mean = 2.13) and *decarbonization sceptics* (mean = 2.00). Distinguishing between internal and external stakeholder pressure, our results show that the differences regarding internal stakeholder pressure are more profound. Internal stakeholder pressure is above average in the groups of *decarbonization all-rounders* (mean = 3.07) and *total supply chain decarbonizers* (mean = 2.92), whereas external stakeholder pressure is only above average in the group of *decarbonization all-rounders* (mean = 2.51), but below average in all the other groups.

TABLE 2 Predictors	of decarbonization types: s	takeholder pressure, st	akeholder legitimacy, gree	en capabilities and	green innovation.			
	Stakeholder press	ure and stakeholder legit	imacy				Green capabiliti	es and green innovation
Decarbonization type	Stakeholder pressure	Internal stakehold pressure	er External stakehr pressure	older Gre credit	en Green vility image	Green reputation	Use of enviror	mental management ystems
Decarbonization all-rour	nders 2.78	3.07	2.51	3.99	3.85	3.81	0.81	
Internal supply chain decarbonizers	2.13	2.40	1.91	3.55	3.44	3.41	0.68	
Total supply chain decarbonizers	2.44	2.92	2.15	3.93	3.72	3.65	0.76	
Decarbonization laggarc	ls 2.30	2.57	2.13	3.53	3.43	3.39	0.70	
Decarbonization sceptic	s 2.00	2.57	1.98	3.38	3.30	3.26	0.70	
Total sample mean	2.38	2.68	2.16	3.71	3.57	3.53	0.73	
χ^2 -test (<i>p</i> -value)	604.42 (.095)	171.43 (.021)	168.50 (.080)	48.31 (.0	132) 180.90 (.467)	121.64 (.543)	127.96 (.144)	
TABLE 2 (Continued								
	Green capabilities and gree	en innovation						
				Green				
Decarbonization type	Organizational emission reduction measures	Use of green certifications	Sustainability professionalism index	innovation (overall)	Business model innovation	Production and process inno	d logistic Pr vation inno	oduct Service vation innovation
Decarbonization all- rounders	0.49	0.32	0.63	1.88	1.77	2.25	1.93	1.56
Internal supply chain decarbonizers	0.31	0.22	0.49	1.74	1.44	2.08	1.94	1.45
Total supply chain decarbonizers	0.42	0.28	0.58	1.93	1.70	2.26	2.05	1.67
Decarbonization laggards	0.42	0.31	0.55	1.77	1.63	2.09	1.75	1.59
Decarbonization sceptics	0.32	0.19	0.50	1.55	1.46	1.75	1.71	1.30
Total sample mean	0.40	0.28	0.56	1.80	1.62	2.14	1.89	1.54
χ^2 -test (<i>p</i> -value)	65.58 (.007)	41.97 (.013)	347.52 (.220)	77.348 (.005)	22.401 (.004)	25.884 (.001)	13.8((.087)7 18.586 (.017)

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	Decarboniz	ation ambitions						Structural fir	n characteristi	cs
Decarbonization type	Priority	of CO ₂ -reduction (c emissions)	own Prio	rity of CO ₂ -re	duction (entire su hain)	pply Development of CO emissions	2 ⁻ Firm size	Firm age	Family ownership	B2B firm
Decarbonization all-rounders	4.51		4.10			1.45	317.24	58	%6t	67%
Internal supply chain decarbonizers	3.55		3.25			1.72	251.50	48	18%	74%
Total supply chain decarbonizers	4.22		3.95			1.41	285.24	48	51%	76%
Decarbonization laggards	3.97		3.56			1.54	350.87	52 ,	%Zt	63%
Decarbonization sceptics	3.21		2.79			1.65	278.96	44	54%	79%
Total sample mean	3.99		3.63			1.55	302.22	49.03	%6t	70%
F-test (p-value)							0.69 (.600)	1.57 (.181)		
χ^2 -test (<i>p</i> -value)	109.327 (.0	(00)	11.22	29 (.189)		93.696 (.000)		J).5869 (.965)	6.674 (.154)
TABLE 3 (Continued)										
	Structural firm characteristics	Firm performanc	ce and strategy							
Decarbonization type	B2C firm	Growth ambitions	Profitability	Sales growth	Production depth	Niche versus broad market coverage	Cost focus strategy	Quality fo strategy	cus Inno	vation focus strategy
Decarbonization all- rounders	5%	3.8	3.51	3.41	3.86	3.23	3.45	4.29	4.07	
Internal supply chain decarbonizers	8%	3.45	3.29	3.40	3.66	2.86	3.17	4.19	4.03	
Total supply chain decarbonizers	5%	3.42	3.30	3.33	3.80	2.88	3.10	4.32	3.86	
Decarbonization laggards	3%	3.38	3.26	3.25	3.87	2.88	3.17	4.14	3.91	
Decarbonization sceptics	7%	3.35	3.0	3.12	3.29	2.61	3.28	3.89	3.78	
Total sample mean	5%	3.50	3.32	3.33	3.78	2.94	3.22	4.20	3.96	
F-test (p-value)										
χ^2 -test (<i>p</i> -value)	1.068 (.899)	21.068 (.176)	14.546 (.558)	23.696 (.096)	17.906 (.329)	16.926 (.390)	31.0123 (.013)	22.732 (.121) 30.62	9 (.015)

characteristics.
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TABLE 4

	Industry charact	eristics									
Decarbonization type	NACE 20 Chemicals and chemical products	NACE 21 Pharmaceutical products	NACE 22 Rubber and plastic products	NACE 23 Non-metallic mineral products	NACE 24 Basic metals	NACE 25 Fabricated metal products	NACE 26 Computer, electronic and optical products	NACE 27 Electrical equipment	NACE 28 Machinery and equipment	NACE 29 Motor vehicles, trailers and semi- trailers	NACE 30 Other transport equipment
Decarbonization all-rounders	11.11%	2.02%	17.17%	6.06%	4.04%	16.16%	8.08%	12.12%	20.20%	2.02%	1.01%
Internal supply chain decarbonizers	4.76%	1.90%	8.57%	5.71%	3.81%	24.76%	9.52%	4.76%	30.48%	3.81%	1.90%
Total supply chain decarbonizers	5.00%	3.36%	16.25%	7.5%	5.00%	20.00%	8.75%	8.75%	23.75%	3.75%	1.68%
Decarbonization laggards	6.72%	1.25%%	10.84%	10.08%	5.04%	25.21%	5.88%	6.72%	22.69%	2.52%	%0
Decarbonization sceptics	7.14%	0	14.28%	0	10.71%	10.71%	7.14%	14.28%	28.57%	7.14%	%0
Total sample mean	6.96%	2.25%	12.76%	6.96%	4.87%	21.11%	7.89%	8.35%	24.59%	3.25%	1.13%
χ^2 -test (<i>p</i> -value)	3.9040 (.419)	1.84 (.766)	5.085 (.279)	4.300 (.367)	2.475 (.649)	5.37 (.251)	1.153 (.886)	5.322 (.256)	3.49 (.479)	2.196 (.700)	2.076 (.722)
Abbreviation: NACE	, nomenclature stat	listique des activités	; économiques d	ans la Communau	té européei	nne.					

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The five decarbonization types do not differ regarding green image and green reputation.

4.4.2 | Green capabilities and green innovation

The use of green certifications is above average in the groups of *decarbonization all-rounders* (mean = 0.32 on a scale from 0 to 1), and *decarbonization laggards* (mean = 0.32) but below average in the other three groups. A similar observation can be made organizational emission reduction measures, which also differ across the five groups. Yet, the implementation of Environmental Management Systems (EMS) or the overall sustainability professionalism index does not differ significantly across the five decarbonization types.

We find more differences across the five types regarding green innovation. *Decarbonization sceptics* (mean = 1.55 on a scale from 1 to 3) have a particularly low level of green innovation, whereas *decarbonization all-rounders* (mean = 1.88) and *total supply chain decarbonizers* (mean = 1.93) are above average. The latter type has the highest values among all types in green production and logistic process innovation (mean = 2.26), product innovation (mean = 2.05) and service innovation (mean = 1.67). The only exception is green business model innovation, where the group of *decarbonization all-rounders* shows the highest values (mean = 1.77).

4.4.3 | Decarbonization ambitions

A priority on the reduction of firms' own CO₂-emissions is above average in the groups of *decarbonization all-rounders* (mean = 4.51) and *total supply chain decarbonizers* (mean = 4.22), but below average in the other three groups, specifically in the group of *decarbonization sceptics* (mean = 2.79). In line with this result, significant reductions in firms' own CO₂-emissions over the years are above average in the groups of *decarbonization all-rounders* (mean = 1.45) and *total supply chain decarbonizers* (mean = 1.41), but below average in the groups of *decarbonization sceptics* (mean = 1.65) and *decarbonization laggards* (mean = 1.54). The mean values for firms' actual CO₂-emission reduction along the entire supply chain do not differ significantly across the different decarbonization types.

4.4.4 | Structural firm characteristics, firm performance and strategy

Our results indicate significant differences regarding firms' sales growth and firms' competition strategy. High sales growth is above average in the groups of *decarbonization all-rounders* and *internal supply chain decarbonizers* (mean = 3.41; mean = 3.4), but below average in the groups of *decarbonization sceptics* (mean = 3.12). Significant differences can also be observed in firms' competition strategies. The use of a cost focus strategy is above average in the groups of

decarbonization sceptics (mean = 3.28) and decarbonization all-rounders (mean = 3.45), but below average in the other three groups. Compared to these findings, the use of a quality focus strategy is only above average in the two groups of *total supply chain decarbonizers* (mean = 4.32) and *decarbonization all-rounders* (mean = 4.29), but below average in the other three groups.

The mean values for firm size, firm age, firms' focus on B2B and B2C markets and profitability as well as the influence of family ownership do not differ significantly across the five decarbonization types.

4.4.5 | Industry characteristics

The mean values for industry characteristics do not differ significantly across the five decarbonization types (see Table 4).

5 | DISCUSSION

5.1 | Summary of main results

We conduct a LPA to identify specific decarbonization types within medium-sized firms in the manufacturing industry. Based on a sample of 431 medium-sized firms in the German manufacturing industry, we identify five distinct decarbonization types with specific configurations of decarbonization strategies (i.e., internal CO2-reduction, external CO₂-reduction and CO₂-compensation). Decarbonization all-rounders place importance on all three decarbonization strategies and pursue a holistic decarbonization approach. Internal supply chain decarbonizers and total supply chain decarbonizers are process-oriented firms. Internal supply chain decarbonizers prioritize internal decarbonization strategies, whereas total supply chain decarbonizers focus on internal and external decarbonization strategies. Decarbonization laggards are stuck in the middle between the different decarbonization strategies and do not focus on a specific decarbonization approach. Decarbonization sceptics place no importance on any decarbonization strategy. After having identified these types, we explore differences between them with regard to various firm- and industry-level characteristics. The next section interprets these differences and connects them to prior research on the environmental sustainability of medium-sized firms (Table 5).

5.2 | Contributions to the literature

Our findings add to different streams of the sustainability literature focusing on medium-sized firms. Regarding stakeholder pressure and legitimacy, our results support previous literature by demonstrating that (medium-sized) firms facing high stakeholder pressure engage in more sustainability activities than those with low stakeholder pressure (Helmig et al., 2016; Sarkis et al., 2010). Whereas some studies point to a higher influence of external stakeholders, such as regulatory institutions, investors or customers

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 TABLE 5
 Overview of decarbonization types and their main characteristics.

	Decarbonization all- rounders	Internal supply chain decarbonizers	Total supply chain decarbonizers	Decarbonization laggards	Decarbonization sceptics
Decarbonization types					
Decarbonization strategy	Implementation of all decarbonization strategies	Focus on internal decarbonization	Focus on both internal and external decarbonization; no compensation	Stuck in the middle	Little decarbonization efforts across all three strategies
Percentual amount	23%	25%	19%	28%	6%
Comparison by firm cha	aracteristics				
Stakeholder pressure	and stakeholder legitima	су			
Internal stakeholder pressure**	++		+	-	-
External stakeholder pressure*	++		-	-	-
Green image	++	_	+	_	
Green reputation	++	-	+	_	
Green capabilities an	d green innovation				
Sustainability professionalism index	++		+	-	-
Level of green innovation**	+	-	++	-	
Use of green certifications**	++	-	-	++	
Use of environmental management systems	++		+	_	-
Decarbonization amb	bitions				
Priority of CO ₂ - reduction (own emissions)**	++	-	+	-	
Priority of CO ₂ - reduction (supply chain)	++	-	+	-	
Structural firm charac	cteristics, firm performan	ce and strategy			
Firm age	++	_	-	+	-
Growth ambitions	++	-	-	-	
Profitability	++	_	-	_	
Sales growth*	++	+	+	_	
Cost focus strategy**	++	-		-	+
Quality focus strategy	+	-	++	-	

Note: ++= well above average, += above average, -= below average, --= well below average.

*Significant at p < .1.**Differences across the five groups significant at p < .05.

(Schmitz et al., 2019; Zailani et al., 2012), other studies point to a higher influence of internal stakeholders, such as firms' management or their employees (Baah et al., 2021; Chassé & Courrent, 2018). Our findings indicate that both internal and external stakeholder pressures impact medium-sized firms' decarbonization efforts (Ernst et al., 2022; Ghachem et al., 2022; Mahapatra et al., 2021). The pressure of WILEY- Business Strategy and the Environment

internal stakeholders seems to be higher, though (Ernst et al., 2022; Graham, 2020). These findings also add to the literature on stakeholder proximity, indicating that close stakeholders have a higher impact on firms' decision-making compared to other stakeholders. These results are in line with Hyatt and Berente (2017) demonstrating that internal stakeholder pressure encourages substantive decarbonization efforts, whereas external stakeholder pressure is associated with the implementation of symbolic decarbonization efforts.

With regard to firms' green image and reputation, we challenge previous studies by showing that a positive green image and reputation does not necessarily correlate with actual sustainability behaviour (Amores-Salvadó et al., 2014). Specifically, our findings indicate that firms with a positive green image and reputation do not have a more advanced decarbonization strategy. It seems that medium-sized firms seem to not use decarbonization efforts to increase their trustworthiness and legitimacy with stakeholders or to strengthen their competitive position on the market (Harrison et al., 2010).

Regarding green capabilities, our findings show that possessing green capabilities as such does not have a strong impact on the actual decarbonization approach taken. The situation is different for green innovations, which enable firms to respond to market changes (Ghachem et al., 2022; Meckling & Nahm, 2019) and reduce the costs associated with emission cuts (Jenkins & Karplus, 2016; Meckling et al., 2017). We show that high levels of green innovations help medium-sized firms to implement substantive decarbonization strategies reducing CO_2 emissions from their own processes and products (Li et al., 2022). Prior research shows that this can have implications on performance and competitiveness (Geels, 2002; Gürlek & Tuna, 2018).

Our findings also contribute to previous studies about the intention-action gap regarding sustainability showing that specific climate change targets positively shape firms' decarbonization attempts (Dahlmann et al., 2019; Quintás & Martínez-Senra, 2024). We could show that medium-sized firms that maintained or even increased their CO₂-emissions over the years do mainly focus on a single decarbonization strategy. These findings are not in line with Weinhofer and Hoffmann (2010), who showed that large firms that use a combination of CO₂-strategies are emitting the same amount of CO₂ compared to firms that concentrate on a single decarbonization strategy. In contrast, our findings reveal that medium-sized firms that follow a diverse set of decarbonization strategies produce *less* CO₂-emissions, compared to firms that focus on a single decarbonization strategy.

Our findings further show that a firm's competitive strategy can explain differences in its configuration of decarbonization strategies. We find that firms following a cost focus strategy place less importance on decarbonization and are less likely to pursue a holistic or advanced decarbonization strategy. Reasons could be their aim to keep their operating costs low and not to jeopardize their competitive advantage (França et al., 2023; Hafner et al., 2022; Qiao et al., 2020). In turn, firms following a quality focus strategy seem to pursue rather holistic and substantive decarbonization approaches, which could be part of their quality promise. Hence, decarbonization could actually create value for them and help them to build and maintain a competitive advantage (Dess & Davis, 1984; França et al., 2023).

Interestingly, we could not find statistically significant differences across decarbonization types regarding firm size and family ownership. These findings are in contrast to previous studies showing firm size as a determinant of decarbonization. For example, Damert and Baumgartner (2018) and Weinhofer and Hoffmann (201008) identify a positive influence of firm size on decarbonization. Similarly, the study of Lee (2012) indicates that small firms employ fewer environmental practices than large firms. The fact that we do find a significant influence of family ownership on firms' decarbonization strategies could be due to varying levels of family owners' socioemotional wealth (Li et al., 2023) or family owners' individual decarbonization goals and strategies. We thereby add to the discussion about the impact of family ownership on environmental sustainability (Li et al., 2023; Lorenzen et al., 2024) showing that family ownership as such seems not to be a decisive factor. Further, we could not show any significant differences in firms' profitability and growth ambitions across the decarbonization profiles. These findings indicate that firms' financial performance and their intended growth do not directly influence their decarbonization strategies. Although decarbonization is costly and often requires fundamental changes in the supply chain, it seems that a high profitability is not necessarily needed to invest and allocate the relevant resources needed for decarbonization (Franca et al., 2023). This is especially relevant for medium-sized firms, which are often privately owned and have restricted access to external financing. The fact that no differences regarding growth ambitions can be observed across decarbonization types means that the decarbonization approach taken is not a matter of ambitions but rather a matter of firm strategy and capabilities (as our other results indicate).

5.3 | Practical implications

Our study has implications for owners and managers of medium-sized businesses and policymakers. First, our results suggest that profitability and growth do not necessarily conflict with an ambitious and consistent decarbonization strategy. Firms that have high profitability and growth ambitions seem also to be able to follow an ambitious and substantive decarbonization approach. These findings challenge the traditional view that environmental sustainability approaches are costly but rather suggest that firms can in fact pursue sustainability goals alongside profitability and growth objectives. Policymakers could use these results to encourage decarbonization efforts, as they do not appear to impede firms' economic growth.

Further, our results show that an ambitious and holistic decarbonization strategy is the result of a focus on green innovation. This includes the development of the necessary expertise and skills in this area and a considerable investment of time and money. Policymakers can use these findings to motivate firms to consistently invest in their own green innovation capabilities. They should also encourage firms to seek inter-firm cooperations, where they exchange and bundle sustainability knowledge, resources and capabilities. Our findings demonstrate that there is still some way to go to encourage firms to become more proactive in their decarbonization efforts. As shown by our results, almost a quarter of firms are still rather passive and employ a wait-and-see approach towards decarbonization. This can be a risky strategy in view of the many sustainability requirements that firms will have to deal with in the not so far future. To support these firms in their decarbonization attempts, policymakers should communicate clear guidelines and framework conditions regarding decarbonization. This would help firms to better structure and implement their decarbonization attempts and assign the necessary resources needed for change.

5.4 Limitations and future research

Our study is not free of limitations. First, we draw on a sample of firms in the manufacturing industry. Even though we control for differences within the manufacturing industry, differences in mediumsized firms' decarbonization strategies could exist between industries. As the manufacturing industry has a significant contribution to the global CO₂-emission levels, a potential selection bias could exist regarding the decarbonization strategies pursued. Future research should try to take this into account and account for a broader range of industries to become more representative for the entire spectrum of the economy. It would also be a good idea to extend the sample to the group of small and micro firms following Gomes and Pinho (2023). Another limitation of our study concerns the focus on a single country. Focusing on a sample of German manufacturing firms prevents us from comparing the configuration of medium-sized firms' decarbonization strategies across a broader set of geographical and cultural regions that differ in type and extent of environmental regulations. Future research could take this into account. Besides that, our study finds that differences exist regarding decarbonization strategies within the group of medium-sized firms. We find that the decarbonization approach taken is influenced by a large number of internal and external factors, such as innovation capabilities, competitive strategies and stakeholder pressures. To develop a fuller picture about the entire spectrum of predictors, one could focus on factors that our study was not able to cover such as organizational culture or hierarchical structure. It would also be interesting to delve deeper into individual-level factors such as CEO personality and/or education. Lastly, future research could go deeper into the motives and goals of decarbonization strategies in medium-sized firms. This would enhance our understanding of the underlying psychological, economic and strategic factors influencing a firm's commitment to CO2-emission reduction and help policymakers in designing more effective macro-level strategies that resonate with different types of firms, ultimately leading to more widespread and effective decarbonization efforts across industries and sectors.

ACKNOWLEDGEMENTS

Open Access funding enabled and organized by Projekt DEAL.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Block, J., Lorenzen, S., & Steinmetz, H. (2024). Decarbonization types of medium-sized and mid-cap firms in the manufacturing sector. *Business Strategy and the Environment*, *33*(8), 8833–8850. <u>https://doi.org/10.1002/bse.</u> 3947