

Research

Carbon management strategies of the automotive sector responding to the European fleet-wide CO₂ emission targets

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Received: 1 September 2024 / Accepted: 28 March 2025

Published online: 29 April 2025

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Abstract

The automotive industry plays an important role in achieving the global climate targets. The EU has adopted ambitious restrictions for vehicle emissions, setting fleet-wide reduction targets, while granting automotive companies significant flexibility in meeting these targets. Strategic responses display a broad range of actions reflecting both genuine and escape strategies. A comprehensive framework is applied in the study to evaluate the typical management actions taken by automotive companies. Content analysis of company reports and sectoral reports revealed a wide variety of management strategies, which extend beyond previously known strategies. Only some of these strategies can be expected to reduce global emissions, whereas creative solutions for carbon governance only ensure compliance with emission targets without leading to global CO₂ emission reduction. Based on the results of this study the efficiency of the regulation may be questioned.

Highlights

- Automotive manufacturers are challenged by the European fleet-wide CO₂ emission targets
- Strategies were identified that function as escape strategies while maintaining global carbon emissions levels
- The results of the analysis question the efficiency of the regulation

Keywords Carbon management strategies · Automotive industry · Market collaboration · Decarbonization · Sustainable value chain · Downstream emissions

1 Introduction

During the past few decades, fossil fuel use has led to significant increase in greenhouse gas emissions. This increase has occurred in tandem with the growth of the global economy and the spread of globalization. It is now vital that economies decarbonize to limit global warming. Most economic sectors are required to take active decarbonization measures to avoid the tipping point [1, 2]. The effects of CO₂ are cumulative. Regardless of where it is emitted geographically, CO₂ contributes to the global problem. With the exception of indirect emissions from the manufacture of fuel and automobiles, the transportation sector is accountable for one-third of all CO₂ emissions and one-fourth of all greenhouse gas emissions in the EU [3]. Passenger cars are responsible for more than half of the EU's greenhouse gas emissions

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from the transport sector [4]. Global consensus exists on the importance of reducing automobile carbon emissions to mitigate the impacts of climate change [5–7]. That is why the European Union is implementing ambitious restrictions on automobile carbon emissions.

According to Regulation 2019/631 of the European Commission, a restriction of 95 g/km at fleet-wide emission was implemented. The 95 g/km CO₂ limit equals a gasoline consumption of approximately 3.8 L per 100 km. The fleet level target employs a novel calculation methodology, as it refers to fleet level. The regulation allows that individual cars do not necessarily have to meet the target. Car manufacturers have to ensure that the average emissions of all new cars they sell meet the fleet-level target. The manufacturer's portfolio can include a variety of cars with different levels of emissions. The aim is that the portfolios' average emissions on a fleet level have to comply with the fleet-level target regulations. Thus, the regulation of the EU does not pertain to individual vehicles but establishes targets per manufacturer that are counted by average across all new vehicles sold [8, 9]. Zero-carbon electric cars may offset some emissions from fossil-fuelled cars. Consequently, the sale of electric cars reduces the overall emission and helps meet the target. A failure to comply with the regulation results in a substantial penalty of 95 euros for every additional gram per kilometer of emissions. Thus, an overshooting by 10 g/km of emissions may result in an increased cost of up to 950 euros per car.

During the period from 2020 to 2022, selling zero or low emission vehicles were also incentivized by giving them higher weight when calculating the average emissions of the fleet sold. During a transitional period, innovative technologies were eligible for a discount. The targets applicable from 2025 are derived from the Worldwide harmonized Light vehicles Test Procedure (WLTP) and have been defined in Commission Implementing Decision (EU) 2023/1623 [9]. The CO₂ emissions for cars will be set to 93.6 g/km between 2025 and 2029 and 49.5 g/km between 2030 and 2034 [9]. The regulation is characterized by a combination of strictness and flexibility. It mandates the strict 95 g/km CO₂ emission target. At the same time, it permits a wide range of compliance strategies.

Automotive companies have responded to the regulation by implementing a wider range of strategic approaches. The objective of this article is to reveal and classify these strategic responses in the European market using the framework proposed by Damert et al. [10]. The article also identifies environmentally genuine and escape strategies [11]. Implementing genuine strategies at a global level can effectively reduce carbon emissions. Escape strategies may be advantageous for the company from a business perspective, but they do not contribute to emission reductions at a global level. Instead, they simply shift the negative impacts to different regions or other manufacturers. The European fleet-level target regulation pertains to the emissions of the final product. The emission of the manufacturing process is irrelevant to the target. Each car manufacturing companies selling cars on the European market, including Asian or American manufacturers, must comply with the regulation. These emissions are included within scope 3 downstream emissions in the value chain.

The rest of the paper is structured as follows. A literature review of carbon management strategies is presented in Sect. 2. Data collection and qualitative content analysis are presented in Sect. 3. Identifying and classifying carbon management strategies of automotive manufacturers in the European market are presented and discussed in Sect. 4. In Sect. 5, conclusions are drawn highlighting novel research findings and future directions.

2 Literature review

2.1 Carbon management strategies

Carbon management strategies encompass various actions taken by a company to address the mitigation in greenhouse gas emissions [12]. These actions include measuring and reporting emissions, reducing emissions, engaging in emissions trading, and implementing other measures to mitigate climate change risks, seize opportunities, and enhance corporate competitiveness in a market that is regulated and limited in terms of carbon emissions [12]. The outcome of carbon management strategies is not evident, it may lead to a worldwide reduction, stagnation, or even to increase in carbon emissions [13].

Different models exist in academic literature to classify carbon management strategies. Some models examine the reasons behind the varying responses of companies operating in similar competitive landscapes and categorize strategies according to the intensity of strategic response [12]. Other models are based on the principles of the institutional school and analyze how societal pressures and interactions with social actors can lead an organization shift from a reactive strategy to a proactive strategy, and how institutional pressures influence companies' decisions to climate change challenges [14, 15]. Hoffmann [16] revealed how companies can voluntarily reduce greenhouse gas emissions and its

related business benefits. Kolk-Pinske [17] identified the possible steps of decarbonization a company could take by using a target—organisational embeddedness matrix, while Lee [18] identified six types of carbon management activities examining the activities of Korean companies in response to climate policy challenges. Csutora [11] distinguished between escape strategies and genuine strategies. The escape strategy is employed to maintain growth objectives and to focus primarily on sustainability issues that are easy to address and are relatively inexpensive. These strategies reduce the company's risks, do not align with society's carbon reduction goals at the macro level. While these actions have marginal environmental impact. These activities primarily focus on decreasing the company's liabilities. As opposed to this, a genuine strategy creates a breakthrough, and it is effective in creating real environmental impact and reduction in carbon emissions.

Corporate carbon management strategies were explored in the case of two Slovenian manufacturing companies responding to the regulations of the Kyoto Protocol [19]. Cadez and Czerny [20] reviewed the literature on carbon strategies and distinguish among carbon practices, strategies, and strategic priorities. Based on their framework five main corporate strategies were revealed, after examining 158 carbon-intensive companies from three EU nations. Internal carbon reduction includes combustion emissions reduction, process emissions reduction, and lower product output. External carbon reduction can be achieved by reducing supply chain emissions while offsetting and balancing can be considered forms of carbon compensation. The study provides a robust framework for analyzing carbon management in carbon-intensive manufacturing firms. It emphasizes the significance of reducing emissions from both manufacturing processes and external sources, such as supply chains. There are significant variations in the strategies employed by carbon-intensive manufacturing companies related to climate change abatement according to Cadez and Guidling [21]. It was even highlighted by Cadez et al. [22] that after the adoption of the EU ETS, carbon-intensive companies participating in the scheme prioritized measures to minimize greenhouse gas emissions from combustion and industrial activities.

Recently, contrary to expectations, the commitment to green technology has stabilized or possibly decreased at the end of the second trading period.

2.2 Carbon governance, carbon reduction and carbon competitiveness: the framework for carbon management applied by the study

In this study, we apply the framework proposed by Damert et al. [11], where they differentiated between carbon governance, carbon reduction, and carbon competitiveness as corporate objectives, while defining the corresponding carbon management activities. This framework is used in this study to reveal the carbon management activities of automotive companies responding to the EU fleet-level regulation.

1. Carbon governance is the ability of an organization's management to handle the advantages and disadvantages of climate change mitigation strategies and related governance processes [23]. In case of carbon governance, the company solely focuses on implementing carbon management measures that benefit the organisation, without considering whether these actions are transferring adverse effects to other economic actors. Carbon governance includes risk management and organizational involvement. By engaging their staff, organizations can enhance their climate change mitigation efforts [18, 24]. Risk management assesses the possible dangers and outcomes of climate change mitigation initiatives. Organizational responses to the more obvious effects of climate change have been the primary focus of studies on risk management in this area [23, 25].
2. Carbon reduction refers to a company's commitment to reduce its carbon emissions and the implementation of appropriate management actions. Such management actions include carbon measurement and policy, product improvements, process improvements, and carbon compensation [10]. Carbon measurement and policy encompass strategies to reduce greenhouse gas emissions and use corporate systems to monitor emissions. Companies can use lifecycle evaluations to determine how much they want to reduce emissions from their products and innovations [12, 26–28]. Reducing the amount of high-impact products in a company's portfolio [29] or using renewable or recycled resources instead of inputs that produce a lot of greenhouse gases are possible strategies and these actions result in real carbon reduction [30–33].
3. Carbon competitiveness refers to corporate activities retaining competitive advantage or legitimacy. Related activities include developing new products and new markets, stakeholder engagement, corporate communication, and implementing policy initiatives [10]. New markets and product development refer to bringing a product or service to market that incorporates climate change as a differentiating factor, new products are manufactured by innovative technologies that reduce carbon emissions. For product development and technological innovation businesses

may form strategic alliances and work together on R&D [17]. Other forms of alliances can include partnerships with public agencies or other businesses [34, 35]. Stakeholder engagement encompasses a wide range of collaborative efforts between public and private entities that are not intrinsic to a company's core operations [36]. Businesses can influence political decision-makers indirectly through public statements, policy proposals, debates, and funding of scientific studies as a part of carbon competitiveness measures [14, 37]. On the other hand, they can directly influence politicians through lobbying and party funding [38]. Political influence can also come from voluntary self-regulation efforts by businesses [39, 40]. Businesses can disclose their efforts to combat climate change either voluntarily or in compliance with legal requirements in their corporate communications [41, 42].

Based on the literature review of carbon management strategies of companies, the following two research questions were formulated.

R1: Which management activities triggered by the fleet level CO₂ target aim to reduce global carbon emissions?

R2: Which management activities serve as escape strategies that address carbon governance without contributing to global impact reduction?

The analysis aimed to identify and classify management activities by automotive companies in the European market. The first research question seeks to identify through qualitative analysis the actions aimed at reducing carbon emissions.

The novelty of this study is the assessment of the strategic responses of automotive companies to recent EU legislation on fleet-level carbon emission targets. The study demonstrates which strategic responses can lead to CO₂ emission reductions and which strategies serve to delay CO₂ reductions from vehicles, highlighting the allowance of so-called escape strategies as a weak point in European legislation. To the best of the authors' knowledge, no studies have been conducted on the carbon management strategies of the automotive industry, nor on their response to the recent EU regulation. The following section presents empirical data collection and data analysis.

3 Methodology

Content analysis by Nvivo software was employed to investigate carbon strategies and management actions taken by automotive companies in Europe in response to fleet-level target regulations.

The analysis was conducted according to the following steps. First, the manufacturers' sample was established using a filter criterion of the annual revenue of automotive companies in the EU as a measure of significance. After identifying manufacturers, publicly available information on corporate carbon management activities was gathered (see Sect. 3.1.). The available documents were extensively examined and reviewed. Utilizing the acquired insights, relevant sources were collected and coded (see Sect. 3.2). Then the carbon management activities were categorized according to the framework established by Damert et al. [10]. Both co-authors examined and re-examined all reviewed documents and assessed their relevance.

3.1 Data sources

The manufacturing companies included in the analysis were selected based on their annual revenue in the EU. The primary sources of information about carbon management activities of companies were publicly available documents: official websites of the selected car manufacturers, annual company reports and sustainability reports, company materials and press releases. Third-party sectoral reports and articles were also used for the analysis. Data sources can be seen in Table 2 and they are listed in the references section. Data was collected and the analysis was carried out in 2024.

3.2 Data analysis

Nvivo 11 content analysis software was utilized to offer a structured approach for the qualitative data analysis. This software enabled the organization and analysis of non-numerical and unstructured data, thereby enhancing the rigor of our content analysis. Figure 1 provides an overview of the analysis process.

The analysis was conducted following the coding method proposed by Strauss and Corbin [43], prominent researchers of the grounded theory. Grounded theory is a qualitative research methodology, it emphasizes the systematic collection and analysis of data and allows exploratory analysis. The coding consists of three steps: open coding, axial coding, and selective coding [43]. The first step is the open coding, where initial coding involves breaking down data into discrete

parts, identifying concepts, and assigning codes to data segments. Axial coding includes connecting codes, recognizing linkages and patterns among the initial codes to establish categories. The last step is selective coding: the final coding stage focuses on a detailed development of categories, and integrating and refining categories to suit the framework that addresses the research question [44].

Through the axial coding process, categories of carbon management activities were established. Some categories were further expanded, and new ones were created as the understanding of corporate management activities developed. Each code was meticulously scrutinized to verify the possibility of merging codes. During the selective coding, the main codes and categories were subsequently compared with existing carbon management activities using the framework of Damert et al. [10]. Most management actions are known from the academic literature, but some new management actions were also revealed by the analysis.

After the final coding structure was achieved, the corporate carbon management activities were classified according to the framework of Damert et al. [10]. The management activities of automotive companies were evaluated based on their contribution to global carbon reduction.

The analysis includes the management actions from Table 1 that are relevant to the automotive industry and are necessary for achieving the fleet-level target.

Carbon governance regarding the automotive industry includes activities where the company prioritizes the implementation of carbon management measures that exclusively benefit its own interests, disregarding any potential negative impacts on other economic actors.

Carbon reduction refers to actions that aim to reduce carbon emissions, namely product improvement, where more efficient products are designed to comply with the fleet level target. Process improvement, which is a component of the general carbon reduction strategy, is not evaluated since the regulation is not concerned with the car's production process. Similarly, carbon compensation is excluded as it relates to offsetting the emissions of the manufacturing company. Furthermore, the analysis did not consider the involvement of stakeholders.

Carbon competitiveness refers to the activities that yield market advantages for a company, with the explicit objective of reducing carbon emissions, e.g., creating a market for battery electric vehicles or fuel-cell vehicles. All activities of Damert's framework [10] are analyzed, new markets and product development, stakeholder engagement, and political activities, namely lobbying.

As a result of the qualitative research, (1) new carbon management activities were revealed (based on coding using the grounded theory approach), and (2) all carbon management activities were classified using the framework of

Table 1 Corporate carbon strategy framework

	Strategic objective	Related corporate activities
Corporate carbon strategy	Carbon governance	Organizational involvement Risk management
	Carbon reduction	Carbon measurement and policy Product improvements Process improvements Carbon compensation
	Carbon competitiveness	New markets and product development Stakeholder engagement Corporate communications Political activities

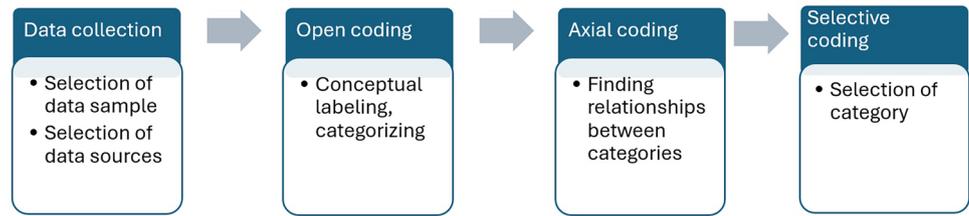
Source: Damert et al. [10]

Table 2 Sources of data analysis

	Automotive corporations
Annual report	Volkswagen, BMW, Mercedes-Benz
Sustainability report	Hyundai, Mercedes, Volkswagen, Toyota
Integrated report	Toyota, Renault
Webpages of companies	Suzuki, BMW

Source: authors' own compilation

Fig. 1 The process of data analysis based on [45]



Damert et al. [10]. The research demonstrates the synthesized results of the coding and classification. (3) Empirical examples support the result of the coding and final classification.

4 Results and discussion

The analysis identified main carbon strategies of automotive companies in the European market and their corresponding management actions, as shown in Fig. 2. This figure is the empirical result of the coding process, where the main themes of carbon management activities are revealed. The analysis also included evaluating the management activities based on their contribution to global emission reduction.

Five carbon management strategies were identified and each included several management actions: product-related strategies, market strategies, cooperation, lobbying, and pricing strategies. The color of the management action indicates whether that action contributes to the reduction of global carbon emissions. Actions highlighted in red do not actually decrease carbon emissions. Actions highlighted in green decrease carbon emissions, such as electrification, efficiency improvement, or strategic alliances.

The following sections provide a comprehensive presentation of the carbon management strategies identified in the analysis with company examples.

4.1 Strategies of automotive companies related to carbon reduction

To comply with increasingly stringent emissions regulations, automobile manufacturers are implementing product-related strategies that require both incremental solutions and genuine technological advancement (Table 3). Two corporate activities were identified: incremental innovation of mature technologies—developing more efficient combustion engines and electrifying vehicles.

Fig. 2 Carbon management strategies in the automotive industry and their impact on global carbon emissions. Source: authors' own compilation

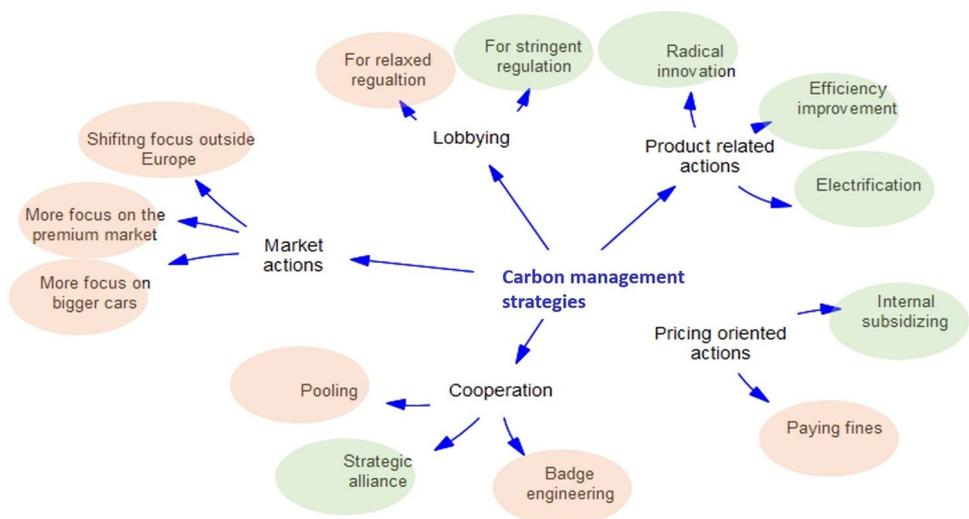


Table 3 Carbon reduction strategies of automotive companies

Strategic objective	Related corporate activities	Corporate activities in the automotive sector
Carbon reduction	Product improvements	Electrifying cars Efficiency improvement

Source: authors' own compilation

4.1.1 Developing more efficient combustion engines

The first subcategory is incremental innovation of mature technologies, which includes developing more efficient fossil fuel-based cars that emit less CO₂. Almost all car manufacturing companies still produce conventional combustion engine-based cars. The transition to zero emission vehicles is still a challenge for many manufacturers that is why they keep on producing more efficient combustion engine vehicles (Table 4).

4.1.2 Electrification of vehicles

The second subcategory of product-related carbon management strategies is the electrification of vehicles, which can be considered an incremental innovation of state-of-the-art technologies. This includes the production of more efficient battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid cars. According to the Life Cycle Assessment (LCA) mentioned in a report from the European Commission, BEVs have a smaller carbon footprint compared to other vehicles [51]. The advantage of PHEVs is that the batteries utilize an electric motor and alternative fuel, such as petrol, to operate an internal combustion engine. Some companies, such as VW, BMW, Mercedes and Renault focus heavily on developing BEV or PHEV vehicles (Table 5). Toyota and Hyundai are committed to producing hybrid cars. Hybrid cars occupy a transitional place between conventional combustion engine vehicles and electric cars.

Table 4 Companies engaged in developing more efficient combustion engine cars

Manufacturer	Corporate actions
Volkswagen	The company set the objective of increasing drive system efficiency with each new model generation – irrespective of whether it is a combustion engine, a hybrid or a purely electric drive system. Specific car models with improved fuel efficiency are traded under BlueMotion name
BMW	BMW developed Efficient Dynamics system to keep fuel consumption and CO ₂ emissions as low as possible
Mercedes	Mercedes-Benz's most economical and environmentally friendly passenger vehicles are marketed under the Blue Efficiency trademark. The set of actions intends to optimize its engine technology further while lowering rolling resistance and aerodynamic drag
Toyota, Mazda and Subaru in collaboration	The three companies are teaming up on new internal-combustion engines. The next-gen engines are intended to provide better efficiency and performance as well as be compatible with alternative fuels

Source: [46–50]

Table 5 Companies engaged in electrifying cars

Manufacturer	Corporate actions
Toyota	Toyota bZ series (beyond zero is a family of zero-emission battery electric vehicles), Lexus EV models
Mercedes	Mercedes-Benz all-electric EQS; Mercedes-Benz EQV (electric mini-van) is the first fully electric car, EQS Sedan (2021)
Volkswagen	VW has already released several electric vehicles under its ID series, including the ID.3, ID.4, and ID. Buzz. Other brands of the VW Group have also started to produce full electric cars: the Skoda ENYAQ, Audi Q3 / Q4 e-tron, E-tron GT, Cupra Born
BMW	BMW i4, BMW i5, BMW i5 Touring, BMW i7, BMW iX1, BMW iX2, BMW iX3, BMW iX, BMW i Vision Circular, MINI Cooper SE and the MINI Countryman SE are good examples of this orientation
Renault	ZOE, Twingo E-TECH Electric launched in 2020, the Kangoo E-TECH Electric van, the Master E-TECH Electric van; 2022. Megane E-TECH Electric

Source: [46–48, 52]

Table 6 Carbon competitiveness strategies of automotive companies

Strategic objective	Related corporate activities	Corporate activities in the automotive sector
Carbon competitiveness	New markets and product development	Radical innovation
	Stakeholder engagement	Increasing the production of electric cars
	Political activities	Co-opetition, strategic alliance for innovation Lobbying for stringent regulation

Source: authors' own compilation

Table 7 Companies focusing on radical innovation

Manufacturer	Corporate actions
Toyota	Mirai—FCV (2014), second generation launch in 2021; plans to introduce an electric-powered Hilux within 6 years
Hyundai	NEXO (2018), flagship for Hyundai's "eco car" portfolio
BMW	BMW i Hydrogen NEXT, BMW iX5 Hydrogen
Renault	Renault Master Van H2-Tech, the Group's first mass-production hydrogen-powered utility vehicle

Source: [49, 52, 56–58]

4.2 Strategies of automotive companies related carbon competitiveness

Five actions were revealed and classified that contribute to carbon competitiveness: radical innovation, increasing the production of electric cars, co-opetition, strategic alliance for innovation, lobbying for stringent regulation and internal subsidizing (Table 6). In the following section, these carbon management actions are explained, and examples are given.

4.2.1 Radical innovation

Radical innovation exemplifies a product-related strategy that creates market opportunities and aims to reduce carbon emissions, thus can be considered a strategy for carbon competitiveness. Radical innovation includes innovation of prospective technologies, such as fuel cell electric vehicles (FCEVs). FCEVs are powered by hydrogen and are more efficient than conventional internal combustion engine vehicles, producing no harmful tailpipe emissions as they only emit water vapor and warm air [53]. While some automakers have already started producing FCEVs (e.g. Hyundai, Toyota), this technology is still in its early stages of development. Table 7 shows examples of manufacturers engaging with radical innovation. Fuel-cell electric vehicles (FCEVs) store energy in a fuel cell stack and a secondary battery. FCEV batteries have a smaller size compared to BEV batteries. Though, fuel cell electric vehicles (FCEVs) encounter obstacles due to the high expenses and intricate nature of the fuel cell stack and hydrogen storage, as well as the limited availability of hydrogen refueling infrastructure at present [54]. Moreover, the restricted availability of hydrogen may serve as a constraint, as the EU could become reliant on hydrogen imports in the future, and the final emission balance of its production is not evidently lower [55].

4.2.2 Increasing the production of electric cars

As a market strategy, by electrifying their product portfolio and selling fewer combustion engine cars, companies aim to contribute to an actual reduction in CO₂ emissions.. This can be classified as a carbon competitiveness strategy. Manufacturers increase the production of electric cars (BEVs) while decreasing the production of petrol vehicles (Table 8). The increased selling of BEVs is a major focus for companies like VW, BMW, Toyota, out of which BMW has the largest market share of BEVs [59]. Most manufacturers are currently focusing on the near future, and they are setting targets for 2025 and 2030.

Table 8 Targets of producing EVs

Manufacturer	Corporate actions
Mercedes	Mercedes aims to offer an electrified variant for every model from Mercedes-Benz Cars in the second half of the decade. They intend to elevate the percentage of electrified vehicles in the new vehicle fleet at Mercedes-Benz Cars to 50%
Volkswagen	VW aims to have 70% of its European sales in electric cars by 2030
Toyota	By 2030, Toyota aims to offer 30 BEV models for the Toyota and Lexus brands worldwide
Hyundai	Hyundai plans by 2035, that all vehicles sold in Europe will be 100% electrified, and by 2040, they plan to achieve a similar goal worldwide, aiming to be a top player in the global EV market
BMW	BMW aims to produce more than 50 percent of its sales volumes from fully electric vehicles by 2030. The BMW Group intends to deliver over 10 million all-electric vehicles to customers by 2030
Suzuki	Suzuki introduced its first battery EV in 2024, and aims to launch a series of compliant HEVs and EVs
Renault	Renault aims to have all-electric or plug-in hybrids for 50% of its vehicles. It aims to electrify 80% of vehicles. Target: 1 million electric vehicles produced by the Renault brand by 2031

Source [49, 52, 56, 57, 60–66]:

4.2.3 Co-opetition

Co-opetition describes the process of working together and co-creating with partners who might also be rivals. It means that a co-opetitive model for value creation emerges when cooperation and competition are combined to create a new type of strategic partnership between businesses [67, 68].

As individual efforts may not be sufficient to create the necessary infrastructure for electric vehicles, co-opetition is a vital strategy for competitors. While the different models of vehicles compete with one another, it is in the best interest of all parties to establish common standards. This facilitates the development of new technologies or the development of a unified and extended infrastructure, such as a charging network. BMW Group, Ford Motor Company, Hyundai Motor Group, Mercedes Benz AG, and Volkswagen Group with Audi and Porsche founded Ionity, as a joint venture company that installs fast chargers, in 2017 to serve the European continent as efficiently as possible with charging stations and to weaken rival Tesla [69]. This company got start-up subsidy from the EU and it contributes to increasing consumer convenience, serving the growing demand and accessibility of EVs [69]. This can be considered a strategically effective and proactive strategic response from the founding manufacturers of Ionity.

Further examples for co-opetition were revealed and provided in Table 9. Forming strategic alliances contributes to compliance with legislation as well as to business opportunities. BMW has been developing hydrogen fuel cell technology with Toyota since 2015 [70]. Ford and Volkswagen entered a strategic alliance in 2020 to collaborate on electric and autonomous vehicle technologies. This alliance allows them to share research and development costs, and benefit from each other's technological advancements. The scale and economics will benefit both businesses as they manufacture medium-sized pickups and commercial vehicles for international markets [46].

Table 9 Co-opetition of automotive manufacturers

Manufacturer	Corporate actions
Volkswagen and Ford	At the beginning of June 2020, Ford Motor Company and Volkswagen AG signed additional contracts within their existing global alliance for light commercial vehicles, electrification and autonomous driving
Volkswagen and Mahindra	Volkswagen Group and Mahindra & Mahindra Ltd. (M&M) have signed the first supply agreement on components of Volkswagen's MEB for Mahindra's purpose-built electric platform INGLO, taking a definitive step further on their joint vision for e-mobility collaboration
Toyota and BMW	Collaboration to work on hydrogen fuel cell technology
Toyota and Subaru	Developing Toyota bZ4X in collaboration
Toyota and Mazda	Toyota had already been collaborating with Mazda since 2015 for EV technologies, Mazda integrates advanced software and hardware systems akin to those used in Toyota vehicles
Suzuki and Toyota	Cooperation relationship with Toyota Motor Corporation in development of advanced technologies including autonomous and battery of electrified cars, business expansion in promising emerging countries

Source: [46, 49, 70–72]

4.2.4 Lobbying for more stringent regulation

Some forms of lobbying aim to contribute to carbon reduction. If companies lobby for stricter regulations, they can promote industry-wide compliance and emissions reductions. The database of the Influencemap [73] displays engagement intensity scores of manufacturers with climate policy. The Influencemap defines lobbying and policy engagement in accordance with the UN Guide for Responsible Corporate Engagement with Climate Policy [74], but the analysis is extended to encompass a broader range of data sources to capture the policy engagement of companies. A few companies lobbying for more stringent regulations are the market leaders in EV production. The Organisation Score measures the extent to which the company's direct activity either facilitates or hinders science-based climate policy. Having the highest organization score in this analysis, Tesla is the strongest promoter of climate policy agreements, [73], supporting policy objectives including zero-emission vehicle mandates and strict greenhouse gas emission standards. With a good Organization Score, Ford and General Motors comply with EU regulations [73].

4.2.5 Pricing strategy

As a pricing strategy, companies might introduce internal subsidies on BEVs, meaning electric cars are sold below cost. This has a clearly positive environmental impact regarding the increased sales of electric vehicles. When Ford introduced the Mustang Mach-E in late 2020, it was competitively priced to challenge Tesla and other electric vehicle makers. Analysts estimated that Ford was selling the Mach-E at little to no profit, and possibly at a loss, to build market share and establish its presence in the EV sector. Volkswagen's ID.3, launched in 2020, was priced to be accessible and competitive in the market. The initial pricing strategy, especially for the entry-level models, suggested that VW was absorbing some of the costs to encourage widespread adoption of its new electric platform.

These examples demonstrate how automotive manufacturers have intentionally set the prices of their electric vehicles below the cost of production. The aim was to gain a larger share of the market, encourage more people to use electric vehicles, and ultimately achieve long-term profitability by taking advantage of economies of scale and technological advancements. A 2024 report confirms that numerous electric vehicles are sold at a loss, and the primary challenge faced by original equipment manufacturers is to generate profits while manufacturing future electric vehicles (EVs) [75].

4.3 Strategies of automotive companies related to carbon governance

Several carbon management activities were identified related to the objective of carbon governance, where automotive companies initiated activities to comply with the EU-fleet level regulations; however, these activities do not primarily aim to reduce emissions. Table 10 summarizes the corporate activities of automotive companies related to carbon governance, while the following section give a detailed overview about them.

4.3.1 Shifting the focus to non-EU markets

Several manufacturers are shifting their market focus from Europe to other regions and expanding their vehicle sales outside Europe. They are implementing a market restructuring strategy (see Table 11). BMW's vehicle sales in Europe are declining from 1,081,600 units to 943,000 units between 2019 and 2023. In the Asian market, 930,800 automobiles were sold in 2019, increasing to 1,073,100 by 2023, with 77% of these vehicles sold in China. In 2023, battery electric vehicles (BEVs) constituted 15% of total vehicle sales, and plug-in hybrid electric vehicles (PHEVs) represented 7%

Table 10 Carbon governance strategies of automotive companies

Strategic objective	Related corporate activities	Corporate activities in the automotive sector
Carbon governance	Organizational involvement	Shifting focus outside Europe More focus on premium cars and bigger cars Pooling Badge engineering Lobbying for more relaxed regulation Pricing strategy of paying penalties

Source: authors' own compilation

Table 11 Shifting focus from Europe to other regions

Manufacturer	Corporate actions
Toyota	Key markets are Japan, China and Southeast Asia. Toyota plans to increase production of ICE vehicles in emerging markets in China and Indonesia, as the regulations are less strict than the EU. As of 2023, China accounted for 20% of total sales, Asia for 14%, and Europe for 11%. Internal combustion engine (ICE) vehicles constitute the smallest proportion of sales, accounting for 59% in Germany, 68% in China, 86% in the USA, and 99% in Indonesia
BMW	Sold vehicles in China and Asia are constantly increasing since 2019, while the European and US market is stagnating. Already in 2023, not Europe but Asia was the largest market of the company. In Asia, a total of 1,073,115 units were delivered (2022: 1,030,987 units, an increase of 4.1%). In China, sales also improved, with orders increasing by 4.1% to 826,257 units (compared to 793,520 units in 2022)

Source: [49, 56, 76]

[56]. In Germany, internal combustion engine vehicles constituted only 59% of Toyota's total sales, while 68% of its total sales in Asia and 99% in Indonesia [49]. One of the several motivations behind shifting the focus from Europe could be to comply with progressively stringent European legislation, which leads to the sale of vehicles with greater emissions in countries with less stringent CO₂ emission regulations.

4.3.2 Focusing on premium cars and bigger cars

Premium cars are typically larger by weight, while larger size is associated with higher CO₂ emission targets. As the size increases, the target becomes more permissive. Certain automobile manufacturers were let to attain elevated fleet average emissions levels due to their vehicles of greater weight. Their pricing structure can accommodate the expenses associated with technological improvements. Numerous manufacturers have made substantial investments in the production of larger high-end vehicles, as shown in Table 12. Contrary to expectations, the average car size is growing instead of shrinking.

Between 2020 and 2030, SUV and light-commercial vehicle production is expected to increase by 7% as a percentage of all light-duty vehicle production. [59]. For example, sport utility vehicles (SUVs), which are highly resource-intensive to produce and polluting while in operation, constitute the central element of Volkswagen's sales strategy for its foremost brand. Despite advancements in fuel efficiency and electrification, the growing popularity of heavier and less efficient vehicles such as SUVs has counteracted the recent progress made in energy efficiency and emissions reduction in the passenger car fleet. SUVs emit approximately 20% more emissions than an average medium-sized car. Increasing production of SUVs and light trucks threatens decarbonization [77].

Table 12 Companies launching premium cars

Manufacturer	Corporate actions
BMW	BMW X7 and the upcoming iX electric SUV, Rolls-Royce Spectre
Volkswagen	Audi e-tron series, Porsche Taycan, and Bentley's hybrid models
Mercedes	EQ line of electric vehicles, such as the EQS

Source [46, 48, 56]

4.3.3 Pooling

To meet the emissions targets, manufacturers have the option to collaborate and merge in pools [9]. The calculation of carbon emissions can be done on a pool basis, rather than on an individual manufacturer basis. This strategy enables companies to effectively manage their fleets' collective emissions. Pools are dynamic, changing from year to year.

Fiat pooled with Tesla to meet emission targets and avoid penalties in 2019. The emissions of Tesla, a producer of zero-emission electric vehicles, were calculated alongside Fiat's, enabling Fiat to take advantage of a considerably larger emissions allowance. In the same year Toyota pooled with Mazda [78]. Volkswagen pooled with Ford in 2020 and in 2022, so that emissions were calculated for their common pool. Further cases of pooling are provided in Table 13. These pooling arrangements exemplify how automakers can strategically cooperate to fulfill regulatory mandates. Manufacturers of vehicles with higher emissions can evade significant penalties by forming partnerships with manufacturers of vehicles with lower or zero emissions. In 2022, Honda and Land Rover, both of which produce vehicles with considerably high emissions, formed a pool with electric car manufacturer Tesla, to comply with the European regulation. Pooling can be considered a defensive and evasive strategic response from manufacturers.

4.3.4 Badge engineering

Manufacturers in the automobile industry sometimes practice badge-engineering (or rebadging), a strategy in which identical vehicles are marketed and sold under different names and brands. This enables companies to expand their market reach and share development costs. An example is the Suzuki Swace, which is a variant of the Toyota Corolla's body. This helped Suzuki to comply with emission limits, even though this might not be the sole reason for badge engineering. Suzuki is expanding its model range with the new Across SUV, which is a rebadged version of the Toyota Rav4 [81]. The Mazda 2 Hybrid is a rebadged Toyota Yaris Hybrid sold exclusively in Europe [82]. Badge engineering is presently employed for vehicles with below-average carbon emissions but with internal combustion engines. Badge engineering hinders long-term innovation rather than fostering it, as vehicles' core technology, design, and engineering remain unchanged. It is a short-term, cost-saving management action instead of investing in R&D. It yields immediate cost reductions by lowering production expenses, but it undermines a company's long-term competitiveness.

4.3.5 Lobbying for more relaxed regulation

Despite the advancement of climate legislation, the global automobile industry remains one of the most vocal opponents of it. The Performance Band of the Influence Map comprehensively assesses a company's climate policy engagement, incorporating both its individual efforts and those of its industry groups. According to this, ten of the fifteen automakers under analysis received a Performance Band score of D or D+, indicating that their policies do not align with achieving the Paris Agreement goals. The report indicated that Toyota is the third-most obstructive organization in the world for influencing governments enacting climate policy. One of the factors contributing to Toyota's rating was the company's

Table 13 Automotive manufacturers forming a pool with the year of pooling

Manufacturer	Year of pooling
Toyota—Mazda	2018
Fiat—Tesla	2019, 2020–21
Tesla—Honda	2020–2021
Toyota—Suzuki	2020
Volvo and Ford	2020–2021
Hyundai—Fiat Chrysler Automobiles (FCA)	2020–2021
Volkswagen—MG motor	2021
Mazda and Toyota	2021
Tesla-Honda-Jaguar Land Rover	2022
Mazda—Subaru—Suzuki—Toyota	2022
Renault—Nissan—Mitsubishi	2023
Toyota—Subaru—Suzuki	2023

Source: [78–80]

previous efforts to retain internal combustion engines, as the company has fought against legislation that will gradually replace internal combustion engines in 2020 and 2021 in favor of electric vehicles [73]. Toyota has consistently resisted the phasing out of internal combustion engines (ICE) and the implementation of zero-emission vehicle (ZEV) requirements worldwide between 2022 and 2024 [83].

Laggard automakers oppose regulations that will gradually stop the sale of internal combustion engines, although they favor incentives to buy electric cars. Toyota is not alone in opposing stringent regulations, BMW (18th), Daimler (24th), and Hyundai (25th) are joining the list of the Influencemap [73]. Automakers lagging behind in electric vehicle production such as Suzuki, also oppose the objectives of the Paris Agreement.

Smaller manufacturers, often producing luxury or performance vehicles, argued that they face disproportionate costs in adapting to strict emissions targets. Manufacturers that register fewer than 1,000 new cars or vans in the EU per year are exempted from achieving a specific emission target for the following year, unless they choose to request a derogation. Manufacturers registering fewer than 10,000 cars or 22,000 vans may, under specific conditions, seek 'small volume manufacturer' derogation from their assigned emission target due to their limited production volumes. The derogation will no longer be in effect starting from 2036. [84]. However, these manufacturers have much higher average CO₂ emission rates per km, than other manufacturers that are producing in larger volumes [85]. Ferrari, Aston Martin, Bugatti and McLaren are among the notable manufacturers that receive a derogation as a small-volume manufacturer. This derogation permits Ferrari to establish more achievable targets that align with its production capabilities and vehicle types [86, 87]. Exceptions reduce the compliance burden, allowing smaller-volume car manufacturers to meet higher emission limits compared to mass-market manufacturers. By obtaining these exemptions, they can continue producing higher-emission vehicles without being forced to make drastic technological shifts.

4.3.6 Price-oriented action

Strategies related to paying penalties can be considered as a carbon governance action. Certain companies pay penalties for exceeding the emission target. If a manufacturer's fleet of new vehicles exceeds the average CO₂ emissions threshold, they are required to pay €95 for each gram per kilometer of exceedance for every vehicle registered in that year. In 2020, the Volkswagen Group, fell short of achieving the target by recording a final figure of 99.8 g/km. The European Union imposed a fine of €150 million on Volkswagen [88]. However, paying fines and not complying with the fleet-level target is effective only in the short term. If a company is fined once, it usually meets the fleet-level target the following year, which results in a real reduction in emissions.

4.4 Discussion

After reviewing the carbon management measures of automotive manufacturers in the European market, we have identified both positive and negative examples of decarbonization strategies. No previous analysis has been done on identifying and evaluating the carbon management strategies of car manufacturers in the European market. Carbon reduction, carbon competitiveness, and carbon governance actions were revealed.

The first two columns of Table 14 summarize the management actions that were revealed from the content analysis. The third column shows the categorization of these actions according to the carbon management categories defined by Damert et al. [10].

The matrix in Table 15 summarizes the engagement of automotive companies with the identified carbon management actions. The matrix and evaluation are based on a qualitative analysis of a certain number of available corporate reports and third-party documents. The carbon management activities are classified according to the framework of Damert et al. [10].

Companies have already initiated various technological improvements to reduce carbon emissions. These include either increasing the efficiency of internal combustion engines or electrifying their vehicles. We conclude that all product-related strategies, classified as real carbon reduction and carbon competitiveness, are genuine strategies that contribute to real global emission reduction.

Carbon governance strategies can be considered as transitional strategies, as manufacturers intend to apply them until they complete the technological development of their vehicles and catch up in progress. Pooling is observed as a carbon governance strategy that is implemented in the short term. This is an example of a medium-term carbon governance strategy.

Table 14 Carbon management strategies in the automotive industry

	Management actions	Contribution to company strategy
Product-related strategies	Electrifying cars	Carbon competitiveness, carbon reduction
	Efficiency improvement	Carbon reduction
	Radical innovation	Carbon competitiveness
Market strategies	Shifting focus outside Europe	Carbon governance
	More focus on the premium market	Carbon governance
	More focus on bigger cars	Carbon governance
Cooperation	Pooling	Carbon governance
	Strategic alliance for innovation	Carbon competitiveness
	Badge engineering	Carbon governance
Lobbying	For relaxed regulation	Carbon governance
	For stringent regulation	Carbon competitiveness
Pricing strategies	Paying fines	Carbon governance
	Internal subsidizing	Carbon competitiveness

Source: authors' own compilation

Table 15 Summary of carbon management actions

Carbon management strategies	Management actions	BMW	Mercedes	Volkswagen	Toyota	Hyundai	Suzuki	Mazda	Renault
Carbon reduction	Electrifying cars	x	x	x	x	x	x	x	x
	Efficiency improvement	x	x	x	x	x	x	x	x
Carbon competitiveness	Radical innovation	x			x	x			x
	Increasing the production of Evs	x	x	x	x	x	x	x	x
	Strategic alliance for innovation	x		x	x		x	x	
Carbon governance	More focus on bigger cars	x	x	x					
	Shifting focus outside Europe	x			x		x		
	Pooling			x	x	x	x	x	x
	Badge engineering				x		x	x	
	Lobbying for relaxed regulation	x			x				
	Price-oriented action	x		x					

Source: authors' own compilation based on publicly available documents

Source of documents: Efficiency improvement: BMW: [56, p.44, pp. 99–100], Mercedes: [61, p.9, p.72], Volkswagen: [46, p.167], Toyota: [50, p.48], Hyundai: [57, p.23], Suzuki: [89, pp.8–9], Mazda: [50, p.8], Renault: [52, p.26], Electrifying cars: BMW: [56, pp. 100–103], Mercedes [61, p.74], Volkswagen: [46, pp.22–30], Toyota: [49, p.30, p.37, p.79], Hyundai: [57, p.17, pp.26–27], Suzuki: [89, pp.80–83], Mazda: [90, p.24, p.28], Increasing the production of EVs: BMW: [63, p.100], Mercedes: [61, p.69], Volkswagen: [46, p.115, 166], Toyota: [49, pp.27–28], Hyundai: [57, p.17, p.22], [66], Suzuki: [89, p.82], [65, p.13], Mazda: [90, p.24, p.28], Renault: [52, p.20], Radical innovation: BMW: [56, p.103], Toyota: [49, p.27, p.46], Hyundai: [57, p. 26], Renault: [52, p.38], Strategic alliance for innovation: BMW: [70], Volkswagen: [46, p.170, p.176], Toyota: [50, 70, 72], Suzuki: [72], [89, p.19], Mazda: [71], More focus on bigger cars: BMW: [56, p.12, pp.22–23, p.67, 69], Mercedes: [48, p.24], Volkswagen: [46, p.5, p.29, pp.30–31], Shifting focus outside Europe: BMW: [56, p.66–67], [76], Toyota: [49, p.30], Suzuki: [89, p.80], Pooling: [78–80], Badge engineering: [81, 82, p2], Lobbying: [73], Price-oriented action: [88]

There was an unfavorable trend in the size of vehicles produced, namely an increase in sales of larger cars. This strategy works against the reduction of carbon emissions. Carbon competitiveness measures were also identified. Carbon competitiveness can be defined as the set of actions undertaken by a company to gain a competitive edge in the market, with the explicit goal of decreasing carbon dioxide emissions. Radical innovation is considered a carbon competitiveness

measure and is regarded as a proactive strategy, as companies can differentiate themselves from other car manufacturers and create a competitive advantage in the long run. Manufacturers that pioneer groundbreaking technology often lag behind conventional, incremental technological advancements in the short run. Co-opetition of manufacturers is crucial for achieving a critical mass in establishing and developing a standardised infrastructure. The establishment of lonomy by multiple automotive manufacturers serves as a good example for this. Lobbying is a strategic measure taken by companies to safeguard their interests and provide a buffer for the technological transition, rather than evading responsibility.

A limitation of the study is that the research is focused on a dynamic and rapidly evolving market environment. The categorization of strategic types may exhibit a certain degree of stability. However, the European car market continuously witnesses the emergence of novel examples and solutions. The categorization of each manufacturer's carbon management strategy type can also evolve periodically, as manufacturers at the forefront of a specific technology may lose their advantage, and market leaders may become laggards. Furthermore, the aim of the present exploratory analysis was to reveal and classify carbon management strategies in relation to the aim of carbon reduction. The present qualitative analysis did not quantify any reductions in carbon emissions as it goes beyond the scope of the present study.

5 Conclusions

The automotive industry can play a significant role in reducing global carbon emissions when it takes effective measures. The article provides a comprehensive overview of the carbon management efforts in response to EU regulations.

The article aimed to identify which management activities will lead to a real reduction in global emissions when complying with the CO₂ targets set by Regulation 2019/631 [9]. Strategies were discovered that serve as escape strategies as they address carbon governance without decreasing global carbon emissions. Carbon management strategies of Damert et al. [10] gave the theoretical framework of the analysis.

A wide variety of management strategies related to carbon management were revealed. Some categories were identified from prior literature, while additional new categories and actions have also come to light. Carbon reduction strategies effectively reduce global emissions (e.g. electrifying the cars, increasing the efficiency of internal combustion engines). Measures increasing carbon competitiveness also contribute to reducing emissions in the long term (e.g. radical innovation, lobbying for more stringent regulations). In contrast to these, creative solutions of carbon governance only ensure compliance to emission targets, and they do not aim to reduce carbon emissions (e.g. pooling). They consist of superficial measures, as companies prioritise carbon management actions that benefit them, even if this means shifting the potential negative impacts to other economic actors. Carbon governance measures are good examples of escape strategies without aiming significant global impact reduction. Escape strategies were identified among manufacturers who invested less in electric vehicle development. Forming strategic partnerships and engaging in co-opetition, alongside increased investment in charging infrastructure may be essential for regulatory compliance in the future.

While enhancing efficiency can result in emission reductions at the product level, it is important not to overlook the rebound effect. This effect occurs when greater efficiencies enable the use of larger cars, ultimately leading to an increase in emissions. Moreover, the growing trend of traffic and transportation favoring road transport may pose a threat to the global reduction of carbon emissions.

However, companies are not only required to comply with legal regulations, but external stakeholders can also positively influence automotive companies to take decarbonizing measures. Implementing carbon management practices can positively enhance operational performance in the context of sustainability for the environment. Suppliers can play a critical role in driving innovation and compliance throughout the supply chain. Consumers, meanwhile, influence demand patterns and purchasing decisions, thereby shaping the patterns of sustainable mobility solutions. Exploring the impact of external stakeholders could be a promising area of further research in the future.

The introduction of electric vehicles from Chinese manufacturers into the European market has the potential to bring about significant changes. This development could provide European manufacturers with a fresh opportunity to collaborate and achieve the desired fleet-level target. Conducting research on this topic could have significant implications in the future. Further studies may consider the application of other theoretical frameworks for evaluating the carbon management strategy of automotive companies.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Maria Csutora and Zsófia Vetőné Mózner. The first draft of the manuscript was written by Maria Csutora and Zsófia Vetőné Mózner.

Funding Open access funding provided by Corvinus University of Budapest. The research work was supported by the National Research, Development, and Innovation Fund of Hungary under Grant Nr. K-146784.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Clinical trial Not applicable.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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