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Sustainable Business Models: An Empirical Analysis of Environmental Sustainability in Leading Manufacturing Companies

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Abstract: This study thoroughly investigates the role of sustainable business models in enhancing environmental sustainability in leading manufacturing companies. Guided by the United Nations Sustainable Development Goals (SDGs), we empirically analyse the integration of sustainability goals into corporate strategies. This study identifies sustainable business models based on an analysis of the sustainability reports published on the website, examining the strategies and action plans declared by 30 companies that are leaders in the sustainability industry, according to their Dow Jones Sustainability Index World (DJSI World) and S&P Global ESG Scores. The strategies considered are aligned with the following specific sustainability development goals: 6 (water security); 7 (renewable energy); 12 (responsible consumption and production); and 13 (climate action). The dataset contains several variables, each reflecting a particular facet of a company's environmental sustainability, as follows: energy consumption; greenhouse gas emissions; waste management strategies; and water conservation initiatives. We use a multidimensional data analysis technique called multiple correspondence analysis (MCA). After using MCA, we use a hierarchical clustering algorithm with the aim of classifying the different companies. Our findings underscore the presence of seven clusters of companies. Compared to the well-established literature on the topic of sustainable business, the innovative contribution of this study is linked to the identification of reaction time as a strategic variable explaining the different sustainable business models. The study makes it clear that the different business models are linked to reaction time to strategic alignment with environmental objectives. The country in which the company is based is also important. This study provides practical insights for companies aiming to align their practices with SDGs. In fact, the time variable provides important information in this regard and makes it possible to identify different approaches to sustainability as well as strong and weak sustainable business models; the former are characterised by a medium long-term strategic orientation towards environmental sustainability, which can be interpreted as the desire to undertake more solid and structured environmental sustainability strategies.

Keywords: sustainable business models; environmental sustainability; sustainable development goals (SDGs); manufacturing companies; business strategy; multidimensional data analysis

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1. Introduction

The introduction of the Sustainable Development Goals (SDGs) has provided companies with a well-defined roadmap to direct their efforts towards sustainability [1]. These global goals serve as a comprehensive framework covering key areas where companies can make a significant contribution towards the future. The Sustainable Development Goals (SDGs) are a set of 17 goals adopted in 2015 by all United Nations member states as a blueprint to achieve a better and more sustainable future for all by 2030 [1]. The SDGs address the global challenges we face, including poverty, inequality, climate change,

environmental degradation, peace, and justice. The 2030 Agenda aims to raise public awareness of the challenges of sustainable development and define an action plan to overcome them, with the SDGs providing the framework to improve the well-being of the world's population and reduce the harmful impact of climate change caused by human activities [2]. To contribute to global sustainable development, companies must recognise that it is essential to improve their sustainability performance [3]. They can do this by shaping their multidimensional sustainability goals and establishing an internal commitment focused on sustainability [4,5]. In this context, sustainable models are essential, as they are a key factor in achieving the Sustainable Development Goals. To successfully implement sustainable business models, companies must integrate sustainability goals into their business strategy [6].

In summary, sustainable business models are essential to achieving the SDGs, as they can help address the global challenges we face in a profitable and sustainable way. Therefore, sustainable business models can define sustainable value-creation mechanisms while ensuring profitability [4,7]. Sustainable business model innovation, i.e., the process of developing and implementing new sustainable business models, is essential for accelerating progress towards the SDGs, as it can help to create new opportunities for businesses to contribute to a more sustainable future [8]. From this point of view, several researchers have attempted to classify innovative business models as sustainable, including Refs. [4,7,9,10]. According to Wirtz [9], based on the focus of innovation, business model innovation can be divided into three interconnected streams. Technology-oriented flow focuses on using new technologies to create new products, services, or business models. Organisation-oriented flow focuses on changing the way a business is organised in order to improve its efficiency or effectiveness. The strategy-oriented stream focuses on using business model innovation to gain a competitive advantage.

Some researchers have identified the interaction of factors at the organisational, inter-organisational and social levels [7,11]. Boons and Lüdeke-Freund, in Ref. [7], conducted a systematic review of the literature in order to classify previous studies on sustainable business models in terms of technological, organisational and social innovation, to understand how sustainable business models and innovations relate to each other. Based on these three interconnected strands, Boffa and Maffei [4] identified clusters of applications by business models that provide a framework for companies to integrate sustainability into their operations and products. In this way, companies can reduce their environmental impact, create social value, and contribute to the SDGs. Based on three interconnected flows developed by Wirtz [9], Bocken et al. [10] introduced archetypes of sustainable business models in order to support companies in developing sustainable business models. Archetypes are ideal descriptions of possible business models that are achieved by focusing on the key distinctive aspects of certain business model families [12]. These groups of mechanisms and solutions aim to create a common language that can be used to accelerate the development of sustainable business models in research and practice and to assist in the process of integrating sustainability into existing industrial models. The researchers identified the following eight archetypes: maximising material and energy efficiency; creating value from "waste"; replacing processes with renewables and natural processes; delivering features rather than properties; adopting a stewardship role; encouraging self-reliance; re-proposing an activity for society/the environment; and developing scale-up solutions.

Very recent studies have paid increasing attention to the role of exogenous factors in determining the approaches to sustainability of companies. Saleemi [13] highlighted the role of political instability in guiding the behaviour of companies and institutions. Wang et al. [14] examined the mechanism of influence of green finance on sustainable business innovation. Other authors [15] underlined the importance of regulation and information in guiding companies towards sustainable strategic approaches by demonstrating how heterogeneous environmental regulation tools positively moderate the connection between the new media environment and green technology innovation. After introducing the topic of the SDGs and examining the main studies in the literature related to them,

the present study, after an examination of the main studies in the literature on sustainable business models (SBMs), tries to answer two main research questions. First, it aims to explore the most popular environmental sustainability strategies or action plans adopted by the best-performing companies. Second, this study considers whether there are any distinguishable business models.

2. Sustainable Business Model (SBM): The Main Theoretical Approaches

The role of the business model in corporate sustainability has only recently become one of the main goals of sustainability research [16]. Sustainable business models (SBMs), also known as business models for sustainability (BMfS), have become increasingly popular as companies realise the importance of creating value for all stakeholders, including the environment and society. In this study, the terms BMfS and SBM are used interchangeably to refer to business models designed to contribute to sustainable development. Sustainable business models incorporate a triple-bottom-line (TBL) approach, which is a sustainability framework that integrates three dimensions of performance, as follows: social; environmental; and financial [17]. It is also known as the "three Ps": people; planet; and profit [18]. Therefore, companies adopting SBMs must integrate sustainability as an essential part of their value proposition and value creation logic [19]. The business model perspective is a valuable tool for companies to identify opportunities to reduce negative environmental and social impacts while creating new sources of value [20].

There is a lack of consensus on the definition and conceptualisation of sustainable business models, but there are several approaches to understanding, developing, and analysing them [21]. One of the first studies conceptualising the growing need for sustainability-oriented business models also identified a set of guiding principles for organisational growth in terms of sustainability [22]. According to Stubbs and Cocklin [23], an SBM requires organisations to consider sustainability as a core business, recognising that it is not only a moral obligation but also a strategic choice [24]. Therefore, sustainable organisations must define their purpose and objectives in relation to social, environmental, and economic benefits. While profits are critical, they are seen as a tool for achieving sustainability, not the only goal.

From a theoretical point of view, a sustainable business model is defined as a "model in which sustainability concepts shape the driving force of the firm and its decision-making" (p. 104, [25]).

As stated by industry pioneers Stubbs and Cocklin [23], organisations should be seen as part of a larger network that includes the natural environment. Therefore, SBM brings together several elements such as the corporate culture, organisational structure, and its operations at both the company and system level. This system- and enterprise-level perspective is based on the triple-bottom-line approach and, to define the purpose of the company and measure performance, includes a wide range of stakeholders and considers the environment and society as stakeholders [10]. To achieve sustainability at the corporate level, companies adopting an SBM must develop internal structural and cultural capabilities, while to achieve sustainability at the system level, they must collaborate with key stakeholders outside the company, to ensure that the entire system of which they are part is also sustainable [26].

Since the publication of Stubbs and Cocklin [23], several researchers have contributed to the growing body of knowledge in this emerging field, further deepening our understanding of sustainable business models. Lüdeke-Freund, one of the leading authors in the field, provided several conceptual and theoretical definitions. First, he described a sustainable business model as "the system of activities of a company that allocates resources and coordinates activities in a value creation process that overcomes the discrepancy between public and private benefits. That is, a business model for sustainability is the structural model of a business logic that creates the business case for sustainability" (p. 56, [27]), The researcher then proceeded to describe a sustainable business model as "a business model that creates a competitive advantage through superior customer value and con-

tributes to the sustainable development of the company and society" (p. 23, [28]). A more recent definition of a sustainable business model has been provided by Schaltegger et al., (p. 6, [20]):"A business model for sustainability helps to describe, analyze, manage and communicate (i) a company's sustainable value proposition to its customers and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value by maintaining or regenerating social and economic capital beyond its organizational boundaries". The latter definition emphasises the key conceptual aspects of business models and the importance of considering the perspectives of multiple stakeholders and their different perceptions of value. Therefore, the main pillar supporting the definition is that it is not possible to create sustainable value for customers without creating value for a wider range of stakeholders [20]. A sustainable value proposition is the primary source of a company's competitive advantage when implementing an SBM ([19], p. 144, [29]) proposed the following definition of a sustainable value proposition: "We define sustainable value propositions as a promise about the economic, environmental, and social benefits that a company's offering offers to customers and society at large, considering both short-term profits and long-term sustainability". Directly linked to the sustainable value proposition of companies is the concept of sustainable value creation. A sustainable business model is based on the idea of creating a feedback loop in which the value created for customers, the value captured by the company, and the value for the natural environment are mutually reinforcing [19]. Value creation in the context of sustainable business models can be described as the process of creating economic, social and environmental value in a way that is mutually beneficial for all stakeholders. The value for the environment comes from the reduction of environmental impacts. Therefore, it is also important to consider the destruction of value that is avoided by the new business model, in terms of society and the environment [19,30].

In addition to studying the transformation and adaptation of business models, several researchers analysed the topic from different perspectives, in order to broaden the knowledge base of sustainable business models. This multi-layered approach to sustainability can provide a more comprehensive understanding of the problem.

Companies can adopt different business models to integrate different levels of sustainability into their operations. Roome [31] distinguishes between two types of sustainability with implications for business models: weak sustainability and strong sustainability. Weak sustainability is about incorporating environmental concerns into existing business structures and systems, leading to incremental changes. Strong sustainability, on the other hand, is about creating a more sustainable future for the business and society, leading to more radical changes. Therefore, strong sustainable business models are designed to integrate sustainability into the core of the company, while weak sustainable business models use only a few elements of sustainability to make the company more sustainable [19].

3. Methodology

The aim of this study is to identify sustainable business models based on an analysis of the sustainability reports published on websites in 2023 for the year 2022 of a sample of manufacturing companies. Specifically, the analysis will focus on examining the strategies and action plans declared by 30 companies that are leaders in the sustainability industry according to their Dow Jones Sustainability World Index (DJSI World) and S&P Global ESG Scores ("Dow Jones Sustainability World Index | S&P Dow Jones Indices", 2023).

At the beginning, we selected the main environmental strategies adopted by the companies of the sample.

The first domain is resource management; the research is focused on it. These strategies promote the efficient utilisation of resources, including water management, energy management, waste management, and emissions reduction. These strategies align with the following specific sustainability development goals: 6 (water security); 7 (renewable energy); 12 (responsible consumption and production); and 13 (climate action).

In this study, we use a series of statistical approaches to thoroughly explore the structure of the data and the underlying categories [32]. Our goal is to analyse and clarify the underlying patterns and structures in the dataset, which consists of categorical variables indicating measures of corporate environmental sustainability. Our technique is designed to systematically and comprehensively analyse the data and uncover the underlying relationships and clusters [33,34].

The dataset contains several variables, each reflecting a particular facet of a company's environmental sustainability. These factors include company policies on energy consumption, greenhouse gas emissions, waste management strategies, and water conservation initiatives. (Table 1) Our technique requires a thorough descriptive examination of these variables to define the initial distributions and to identify any noticeable patterns or anomalies in the data.

Table 1. The main environmental strategies aligned with SDGs.

Domains	Strategies	Definitions	Focus Areas	SDG
Resource Management	Water Management	Efficiently using and conserving water resources.	• Water withdrawal • Water consumption and intensity	6
	Energy Management	Optimising energy consumption and integrating renewable sources.	• Renewable energy consumption • Energy saving • Electrification	7
	Waste Management	Minimising environmental impact through effective waste reduction and recycling.	• Waste reduction and diversion • Recyclable and renewable materials • Green products	12
	Emissions Reduction	Implementing measures to decrease greenhouse gas emissions.	• GHG emissions reduction • Net zero commitment	13

First, we use a multidimensional data analysis technique called multiple correspondence analysis (MCA), which is designed for use with categorical data. MCA facilitates the search for patterns and interactions between different variables by representing information in a multidimensional space [35–37]; for applications, see [38–40]. Multiple correspondence analysis (MCA) is a technique used to reduce the dimensionality of categorical data. At the same time, this technique allows for the visualisation of complex relationships in a more interpretable space [36]. The dimensions were selected for their ability to distinguish between known categories within the data.

After MCA, we use a hierarchical clustering algorithm [41,42] based on the Euclidean distance metric. In this phase, the observations are grouped into clusters to maximise the variation between clusters and minimise the variance within each cluster. Since these dimensions represent the most significant differences in the data, we focus specifically on the first five dimensions derived from the MCA. The choice of dimensions is crucial, as it represents a trade-off between the need for a comprehensive representation of the data and the desire to avoid overfitting and the complexity of the clustering process.

We use three criteria to verify that the clustering obtained is acceptable and robust: silhouette score, Dunn index, and connectedness [43]. Each of these validation indicators provides a different perspective on the clustering quality. Connectedness measures how closely things are clustered with their closest neighbours and provides information about the local integrity of the cluster structure. The Dunn index measures the compactness and separation of clusters by calculating the ratio of the shortest distance between observations outside the same cluster to the largest distance within the cluster. In contrast, the silhouette score provides a concise visual representation of how well each object fits into its cluster by calculating how similar an object is to its cluster relative to other clusters.

In this respect, the validation of hierarchical clustering was performed also using the silhouette score and the Dunn index [43,44]. The silhouette score is a metric for the cohesion and separation of clusters. In this respect, a high average silhouette score in a dataset would indicate that the clusters are well-defined and that data points had been correctly assigned to their respective clusters. The other validation method considered is the Dunn index, which measures the clustering quality based on the ratio between the smallest inter-cluster distance and the largest intra-cluster distance. In this respect, the higher the Dunn index, the better the separation and compactness of the clusters.

We use a novel technique to determine the ideal number of clusters by averaging the values of the three validation criteria mentioned above. This strategy ensures that separation, compactness, and connectedness are balanced in the final clustering solution, improving the reliability and interpretability of the clustering results.

In addition, we use a PVClust clustering strategy [45,46] to support our main clustering study and identify more specific structures in the data. This approach uses a bootstrap resampling method to assess the uncertainty of the hierarchical cluster analysis. PVClust enables us to assess the stability and reliability of the clusters we find by obtaining approximately unbiased *p*-values for each individual cluster, which is another level of validation in our clustering process.

In summary, our approach uses a thorough a statistical framework to identify and confirm the underlying structure of the dataset. We ensure the robustness and interpretability of our clustering results by combining multiple correspondence analysis, hierarchical clustering that is Euclidean distance-based, and extensive validation procedures such as the relevant use of PVClust.

This approach improves the practical application of clustering methods and the understanding of the underlying data structure we are exploring. It also provides advances in the analysis and in the understanding of corporate behaviour and strategic environmental approaches.

4. Results

In this respect, we start from the original data matrix, starting with the multiple correspondence analysis.

In Figure 1 we have the biplot, a graphical representation of the relationships between the factor space axes (represented in this case by the dimensions Dim1 and Dim2) and the variable categories (represented by the dots), which was generated by multiple correspondence analysis (MCA). The biplot captures the complex correlations in a dataset of corporate environmental sustainability indicators (for information on biplots see [47]).

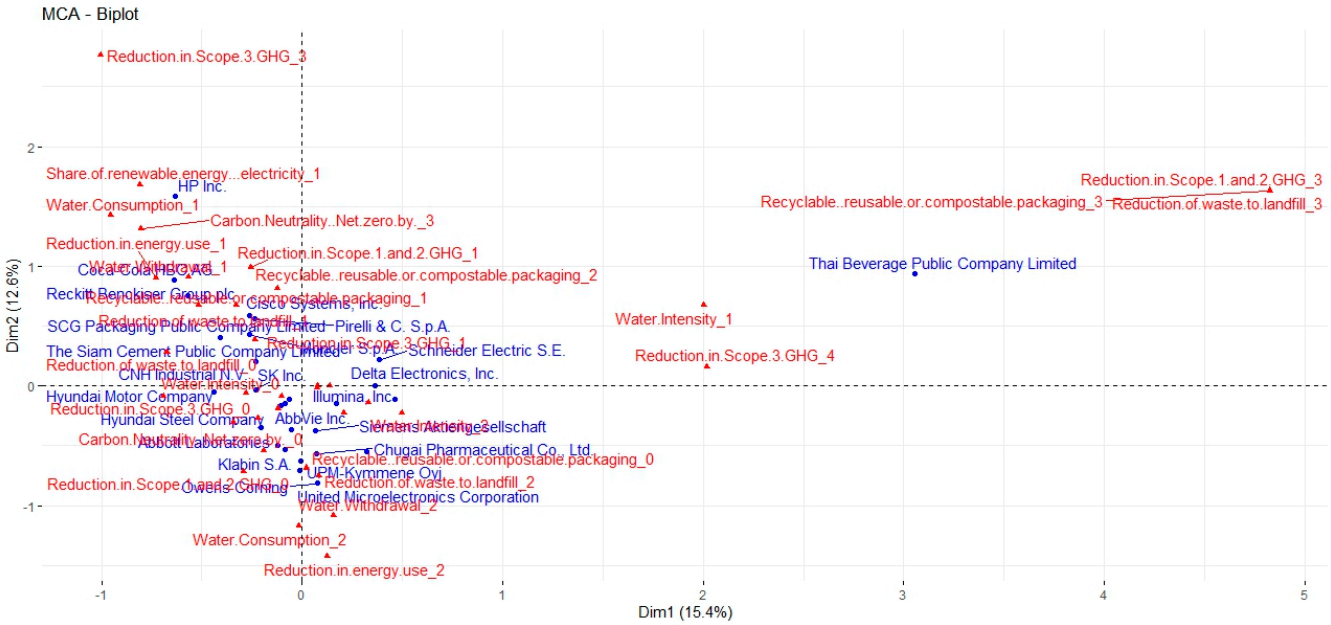

Figure 1. Biplot.

Water-related measures, such as water use and intensity, are contrasted with practices related to reducing greenhouse gas (GHG) emissions in various areas on the horizontal axis, Dim1, which accounts for 15.4% of the inertia. Items explicitly related to carbon footprint reduction include "Reduction.in.Scope.1.and.2.GHG_1" and "Reduction.in.Scope.3.GHG_4" on the right, while "Water.Consumption_2" on the left represents a different set of environmental activities.

Dim2 accounts for 8.2% of the vertical inertia and could indicate a mismatch between the level of resource use and broader environmental commitments. At the top, variables, such as "Reduction.in.Scope.3.GHG_3" and "Carbon.Neutrality.Net.zero.by_3", could represent long-term, ambitious environmental goals. In contrast, the lower part of the double graph, containing the lines "Water Withdrawal_1" and "Reduction.in.Scope.3.GHG_0", could represent more urgent, operational environmental measures.

The proximity of the categories to the axes indicates how strongly they are associated with the corresponding dimensions. Examples of factors that are strongly associated with the factor represented by this axis are "Reusable or compostable packaging_3" and "Reducing waste to landfill_3", both of which are strongly associated with Dim1.

Plotting the individual companies in this space can show how they relate to the previously listed categories. For example, the location of 'HP Inc.' in relation to 'Share.of.electricity.from.renewable.energy_1' indicates that the company has an environmental policy or business profile that is closely linked to the use of renewable energy.

An accumulation of points indicates a potentially common profile across companies and a fundamental link between the categories [36]. Although the graph does not automatically assign membership to the clusters, it suggests groups by visual inspection, which can be confirmed by further cluster analysis.

Biplots provide a compelling visual overview of multivariate data, but it is important to remember that interpretation should be done with caution, especially when point spacing is involved. The relationships shown in the biplot need to be confirmed by further statistical analysis, as the dimensional reduction inherent in MCA means that not all variability is captured in two dimensions. The number of dimensions is chosen on the basis of the interpretability of the same dimensions.

Overall, the MCA biplot shows different environmental sustainability profiles for each company. These can be identified by examining how different companies are committed to reducing greenhouse gas emissions, using resources efficiently, and managing waste.

These results form the basis for further research into companies' environmental strategies and for the subsequent cluster analysis.

In Figure 2, multiple correspondence analysis (MCA) dimensions were used to perform hierarchical clustering, resulting in the dendrogram shown. This dendrogram provides insight into the environmental sustainability initiatives of each company. Hierarchical clustering aims to create a hierarchy of clusters ("ward.D") using an agglomerative technique—as demonstrated here using the Ward method—or a divisive approach.

Ward's approach, which aims to identify compact, spherical clusters by minimising the total variation within them, is well-suited to our study. By choosing this approach, we increase the variability between clusters and promote homogeneity within them. In the Ward approach, the height of the dendrogram represents the distance at which the clusters merge, which is correlated with the increase in the sum of squares as the clusters merge.

When we evaluate the dendrogram, we find several companies with varying degrees of similarity in their environmental sustainability profiles based on the MCA parameters. Larger values indicate less similarity between clusters, and the "height" on the *y*-axis measures this dissimilarity.

For example, the dendrogram shows a large cluster on the right that includes companies such as "Schneider Electric S.E.", "Delta Electronics, Inc.", and "Illumina Inc.". This cluster means that these companies have comparable scores on the retrieved MCA dimensions. This may indicate that they pursue sustainability with similar characteristics or tactics. These companies may have sophisticated, comprehensive sustainability plans that align with many environmental performance indicators.

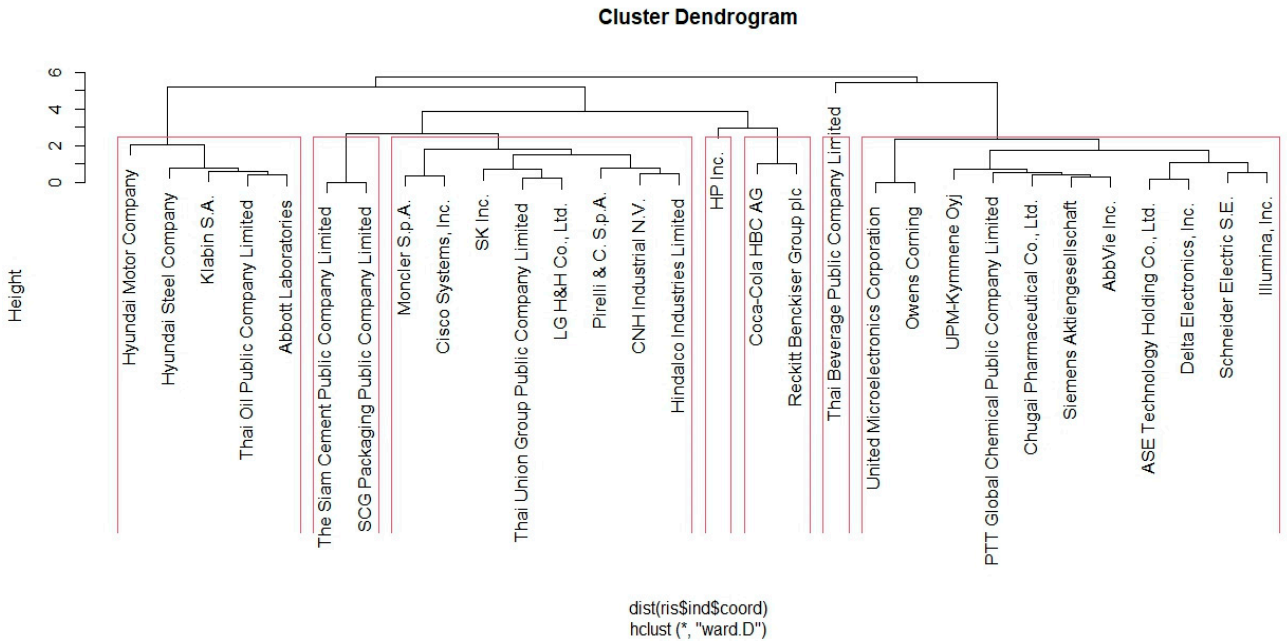

Figure 2. Clusters.

On the other hand, the dendrogram also shows individual companies that appear as individual industries at a higher level, including "Hyundai Motor Company" (Seoul, Republic of Korea) and "Thai Oil Public Company" (Bangkok, Thailand). This suggests that their sustainability profiles are somewhat different from those of the other companies considered, or that they stand out with particular approaches, or results related to environmental sustainability.

In addition, the dendrogram provides a visual aid for determining how many clusters would be most meaningful for the given dataset. The level at which significant mergers occur can be used to determine possible cluster solutions.

The structure of the dendrogram and the external validation criteria should be considered when determining the cut-off level, as it determines the number of possible clusters. For example, a lower cut-off would indicate a significant number of smaller, more homogeneous clusters, while a higher cut-off would indicate fewer, broader clusters.

Looking at the dendrogram, we notice that certain clusters have significant similarity within the group, as indicated by their close connectivity. On the other hand, some branches connect later than others, indicating a less coherent cluster. The interpretability and practical significance of the resulting clusters must be weighed against the art and science of determining the cut-off point.

As described above, the resulting dendrogram is validated with additional clustering validation metrics, such as silhouette scores, the Dunn index, or connectivity measures. By supplementing the visual interpretation of the dendrogram with these measures, we can ensure that the chosen clustering solution is relevant and statistically sound in the context of the environmental sustainability methods under investigation.

Here, dendrogram analysis provides a relevant perspective on the connections and clustering of companies according to their sustainability policies. By combining this hierarchical structure with the dimensions of the MCA and subsequent metrics for cluster validation, we aim to produce a thorough and rigorous analysis that not only stands up to scientific scrutiny, but also provides useful insights into the landscape of corporate environmental sustainability.

Figure 3 shows the dendrogram that is the result of a bootstrap resampling approach applied to a hierarchical clustering analysis using the PVClust algorithm [44]. This technique assesses the degree of uncertainty in the hierarchical clustering analysis. PVClust enhances the traditional dendrogram by adding *p*-values to the branches. *P*-values represent the statistical significance of the detected clusters. The approximately unbiased (AU) and bootstrap probability (BP) values, calculated using multiscale bootstrap resampling, are used to display these *p*-values.

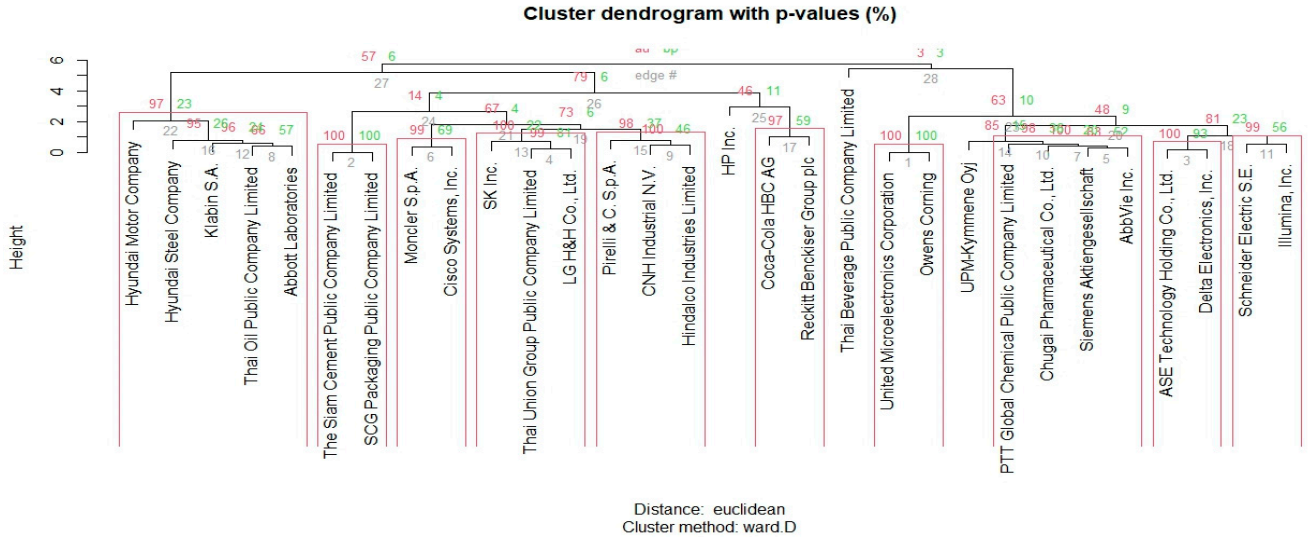

Figure 3. The resulting dendrogram.

Because they consider the bias that occurs during the bootstrapping process, the AU *p*-values, which are located at the beginning of each cluster, are believed to provide a more realistic picture of cluster stability than the BP values. While lower numbers indicate less evidence, AU values closer to 100% indicate a high degree of confidence in the existence of a cluster. For further interpretation and analysis, clusters with high AU values can be considered robust and highly reliable.

The dendrogram uses Euclidean distance to measure cluster dissimilarity, while Ward's approach (ward.D) is used to reduce intra-cluster variation. The explanation of the hierar-

chical structure by PVClust suggests the existence of discrete groups with different degrees of similarity. Interestingly, AU values of 100% indicate that certain clusters—such as "Thai Beverage Public Company Limited" (Bangkok, Thailand) and "Reckitt Benckiser Group plc" (Slough, UK)—have strong data support. This high number indicates that the cluster is statistically significant and not due to chance.

On the other hand, the AU values for certain branches, such as the branch leading to "Hyundai Motor Company", do not provide strong statistical evidence for the uniqueness of the cluster. This suggests that although a certain structure is recognisable, more data or other clustering techniques may be needed to make it more reliable or to reconfirm it.

In addition, the dendrogram indicates possible subclusters within larger clusters. For example, "CNH Industrial NV" (London, UK) and "Honda Motor Co., Ltd." (Minato City, Tokyo) are part of a larger cluster that contains "LG Chem Ltd." (Seoul, Republic of Korea) and "Pirelli & C. S.p.A." (Milan, Italy) as sub-clusters. The confidence level in these finer groupings can be determined from the AU values associated with these sub-clusters.

When analysing this dendrogram in terms of environmental sustainability, clusters with high AU values can be viewed as collections of companies that have comparable performance metrics or business strategies, while clusters with lower AU values can be viewed as regions where business strategies are more diverse or where the data do not differentiate between companies.

Finally, with the added benefit of statistically validating these clusters, the PVClust dendrogram provides a detailed perspective on the linkages among companies with respect to their environmental sustainability initiatives. This methodological approach strengthens the robustness of classical hierarchical clustering. It lends statistical validity to the groups discovered, which can guide targeted initiatives, regulatory decisions, and future studies on corporate environmental sustainability.

5. Discussion

The data resulting from the sample identified suggest different strategies for approaching environmental sustainability, which translate into as many business models.

Starting from the information that companies have declared in their sustainability reports, the paper focused on the following four areas potentially affected by environmental sustainability policies: water management; energy management; waste management; and emissions reduction. For each of these areas, the speed of reaction declared by companies was considered as an indicator to understand the strategic time horizon within which companies declare their intention to undertake sustainable strategies and, therefore, their attitudes towards sustainability.

In particular, four different time periods are considered: the short term (interventions planned by 2025 inclusive), the medium term (interventions between 2025 and 2035 inclusive), the long term (between 2025 and 2045 inclusive), and the very long term, which includes policies planned for after 2045.

The processing of the data suggests the presence of seven clusters of companies, three of which are truly significant in terms of number of companies, each of which corresponds to a specific business model. In the conclusions, we will not refer to the two clusters formed by a single company.

Cases in which companies did not provide answers to the planned interventions were not considered in the identification of clusters. Non-communication could in fact lend itself to multiple interpretations, which makes it impossible to fully understand their intentions regarding the issue of environmental sustainability. In fact, if it is true that non-response could mean a very low sensitivity to sustainability issues, it is equally clear that it could simply mean the desire not to communicate.

The first group (slow- and late-reaction companies) includes five companies—Hyundai Motor Company, Hyundai Steel Company (Seoul, Republic of Korea), Klabin S.A. (São Paulo, Brazil), Thai Oil Public Company Limited (Bangkok, Thailand), Abbott Laboratories—which, in general, show a slow, marked speed of reaction to environmental

sustainability issues. Their business model, in particular, highlights low or no reaction to water and energy management, slow (in a medium-term time frame (by 2035) or no reaction to waste management; they follow only one of the third strategies on the emissions reduction in a long-term or very long-term approach. These companies do not declare anything about water consumption, which could be a minor factor in production. In this cluster, we have the only company on the list from South America. This means that this regional area is not very interested in these strategies

The second cluster (leading company) includes two companies—The Siam Cement Public Company Limited (Bangkok, Thailand) and SCG Packaging Public Company Limited (Bangkok, Thailand)—and corresponds to a business model where environmental sustainability interventions in all areas embrace a short-term time horizon. In fact, companies the declare interventions in the short term, by 2025. Only carbon neutrality (net zero by) interventions are planned for the very long term. The two companies are part of the SCG group, and they have the same strategies. This reaction speed, which can be interpreted as a short-term intervention, can denote great attention to sustainability aspects and a desire to quickly orient corporate strategies towards behaviours oriented towards respect for the environment, in its various components. SCG earned the highest score on the Dow Jones Sustainability Indices (DJSI) in the Construction Materials category in 2023.

The third cluster (waste and emissions reduction-focused companies) comprises eight companies—Moncler S.p.A. (Milan, Italy), Cisco Systems, Inc. (San Jose, CA, USA), SK Inc. (Seoul, Republic of Korea), Thai Union Group Public Company Limited (Samut Sakhon, Thailand), LG H&H Co. Ltd. (Seoul, Republic of Korea), Pirelli & C. S.p.A. (Milan, Italy), CNH Industrial N.V., Hindalco Industries Limited—which show a selective attitude towards the different areas of intervention. Their business model is characterised by low interest in water and energy management, but high interest in short- (less than 2025) and medium-term (between 2025 and 2035) waste and emissions reduction strategies, with the sole exception of carbon neutrality, for which very long-term strategies are envisaged.

The fourth cluster (fast-reaction companies) includes two companies—Coca-Cola HBC AG (Zug, Switzerland) and Reckitt Benckiser Group plc (Slough, UK)—whose business models are based on short-term interventions for water, energy and waste strategies and medium-term emissions-related interventions. They are reacting very quickly to the needs of the environment. One of the reasons for this is that they are aimed directly at the end consumer with products that have to do with drinks and home cleaning. These goods can create problems for people's health; therefore, a quick reaction to sustainability strategies would lead to reducing the risk of scandals. The two companies are based in Europe, where people are very sensitive to health problems.

The last cluster of companies (good companies), is the largest, with 11 companies—United Microelectronics Corporation (New York, NY, USA), Owens Corning (Toledo, OH, USA), UPM-Kymmene Oyj (Helsinki, Finland), PTT Global Chemical Public Company Limited (Bangkok, Thailand), Chugai Pharmaceutical Co., Ltd. (Tokyo, Japan), Siemens Aktiengesellschaft (Munich, Germany), AbbVie Inc. (North Chicago, IL, USA), ASE Technology Holding Co., Ltd. (Kaohsiung, Taiwan), Delta Electronics, Inc. (Taipei, Taiwan), Schneider Electric S.E. (Rueil-Malmaison, France), and Illumia Inc. (San Diego, CA, USA)—and corresponds to a peculiar business model where, in almost all areas, companies state thaat they want to take environmental sustainability actions by 2035. This group seems to denote a proactive attitude towards environmental sustainability, accompanied by a medium-term strategic orientation that could underlie the desire to undertake more structured environmental sustainability strategies. For Carbon neutrality, almost all the companies consider very long periods. If we consider this cluster, we can understand how a country, and the sensitivity towards sustainability of its people, influence the inclusion in a cluster. For example, all companies from Taiwan are included in this cluster.

Two companies, the Thai Beverage Public Company Limited and HP Inc., are following different strategies.

The Thai Beverage Public Company Limited, for example, chooses a short-term strategy for its water strategy, a middle-term strategy for energy, and long and very long strategies for waste and emissions reduction. If we compare this with the other companies on that strategy, they are very slow. In the biplot of Figure 1, we can see that ThaiBev is very far away from the other companies. ThaiBev declare that the company has an interest in expanding on its ESG reporting to include the CDP Climate Change Program, which is one of the most recognised global disclosure and rating frameworks for climate change. They are planning a long-term intervention buy of 100% reduction in waste management, recyclable, reusable or compostable packaging, and a reduction in waste sent to the landfill of 100% for 2040, as well as an emissions reduction target of carbon neutrality (net zero) by 2050, a reduction in Scope 1 and 2 GHGs of 100% by 2040, and a reduction in Scope 3 GHGs of 100% by 2050.

HP Inc. is the only company that also chose a short-term strategy for emissions reduction. This means that they had already started in this direction a long time ago. HP also has a fast-reaction strategy for water and energy and a middle-reaction strategy for waste. If we compare with HP Inc. with other companies, we can see, in the biplot of Figure 1, that the company is not in the circle of the other companies, but is little bit far away, on the top. The company states that: "HP has a long-standing history of climate action. Our ambitious goals are designed to combat climate change by focusing on greenhouse gas (GHG) emissions, circularity, and forests".

6. Conclusions

The purpose of this study was to examine how leading manufacturing companies effectively integrate environmental sustainability into their business models and strategic decisions. Exploring the results brings to light significant personal takeaways that underscore the strategic importance of sustainability for companies, emphasising the economic benefits derived from a comprehensive integration of sustainable practices into business models.

The innovative element of this study, which is part of the now broad line of research on environmental sustainability, is that it has considered the time variable as explanatory of a peculiar strategic approach to the issue of sustainability. It is the time variable that seems to indicate a different attitude of companies towards environmental sustainability, a different degree of incorporation of sustainability into the business strategy and, consequently, a different business model.

The results of the analysis of all the environmental sustainability strategies implemented by the 30 sampled companies indicate a general adoption of similar strategies and approaches to minimise their environmental footprint. The primary focus is resource management strategies, such as water, energy and waste management, as well as emissions reduction targets.

The study shows how the companies can be classified into the following five clusters based on their approach to sustainability strategy connected with the SDGs: slow and late reaction companies; leading company; waste and emissions reduction-focused companies, fast-reaction companies; and good companies. To be part of one cluster is influenced mainly by the country where the company is based and also by the fact that they are directly influenced by the final consumers.

The research findings offer valuable insights into companies' commitments to sustainability, revealing consistent and widespread environmental practices across companies. This study contributes not only to academic reflection on sustainable business practices, but also provides concrete insights for companies moving in the complex scenario of environmental sustainability, promoting a more sustainable and resilient future. It will be interesting in the coming years to investigate whether the declarations resulting from the sustainability reports have been followed by virtuous behaviours and, above all, to verify the economic benefits deriving from a complete integration of sustainable practices into the respective business models.

This study represents the first step in a broader research project aimed at highlighting the peculiarities of sustainable business models by manufacturing companies in the medium to long term. To this end, we plan to expand the sample of companies considered and proceed, in the coming years, with a detailed analysis of the strategies followed in terms of environmental sustainability and their consistency with what is declared in the sustainability reports.

Although the small number of companies and the selection criteria for the companies included in the sample considered represents a limitation of the research, we think that what has emerged from this first analysis of sustainability reports can offer interesting food for thought both to operators in the sector and to management scholars. The starting assumption is that environmental, social, and governance sustainability today represents the beacon that guides the strategy of manufacturing companies. It is, therefore, interesting to observe how companies integrate sustainability planning into business management with clear and measurable objectives over time. The time variable provides important information in this regard and allows for different approaches to sustainability to be identified.

In line with studies on sustainable business models, particularly that by Roome [30], the sample analysed allows us to identify strong and weak sustainable business models; the former adopt a medium long-term strategic orientation towards environmental sustainability, which can be interpreted as a desire to undertake more structured environmental sustainability strategies.

This business model internalises sustainability within the company and elects it as the guideline for strategic choices, through a path of change, including cultural change within the organisation, fuelled by planning that involves all company functions. The companies included in the fifth cluster (good companies) and in the first cluster (slow and late reaction companies) are applying this business model.

Conversely, the weak sustainable business model seems to be characterised by a short-term strategic perspective, where communication–marketing reasons, rather than the individual and voluntaristic drives of individual entrepreneurs or enlightened managers, represent the criteria that guide the adoption of sustainable practices. The fourth cluster (fast-reaction companies), the third cluster (waste and emissions reduction-focused companies) and the second cluster (leading companies) adopt this business model.

We believe that linking the time variable to sustainability by identifying structured strategies and weak strategies represents the main contribution that this study, albeit embryonic, can offer to operators in the sector and to the academic community in general.

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