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MULTINATIONALS' APPROACH TO THE CIRCULAR ECONOMY PRINCIPLES: AN OVERVIEW OF THE ELECTRONICS SECTOR AND ITS SUSTAINABLE EFFORTS

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ABSTRACT

Objective: The aim of this study was to investigate how multinational companies (MNCs) are addressing sustainability issues in their operations and to what degree they adopt sustainable initiatives related to the circular economy (CE) principles. **Method:** We performed a systematic review of the initiatives of 43 MNCs, using their corporate sustainability reports. Our sample was selected based on the rankings of the largest multinationals in the computers and semiconductor industries in 2023, according to *Fortune* and *Forbes* magazines. **Main Results:** Considering the significant outputs regarding production, revenue, and waste generation in these industries, we expected that sustainability concerns such as climate change and carbon footprint reduction would appear in their agendas. Our analysis identified key initiatives aligned with CE principles, such as reuse, reduction, and recycling of materials, resources, and products, and compared the patterns observed in the sample. **Relevance/ Originality:** Our findings are relevant to understanding MNCs' strategy and how they deal with the pressure of enhancing resource use efficiently through the CE approach. **Theoretical/Methodological Contributions:** Identifying how MNCs from the same industry approach CE initiatives through a detailed analysis of their sustainability reports. **Social/Managerial Contributions:** Based on successful initiatives, proposing sustainable actions that other companies can explore.

Keywords: Circular Economy, Electronics, Sustainability Reports.

UMA ABORDAGEM DAS MULTINACIONAIS AOS PRINCÍPIOS DA ECONOMIA CIRCULAR: UMA VISÃO GERAL DO SETOR ELETRÔNICO E DE SEUS ESFORÇOS SUSTENTÁVEIS

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RESUMO

Objetivo: Neste artigo investigamos como as empresas multinacionais abordam questões de sustentabilidade em suas operações e em que medida adotam iniciativas sustentáveis relacionadas aos princípios da economia circular. **Método:** Realizamos uma revisão sistemática das iniciativas de 43 empresas multinacionais, utilizando seus relatórios de sustentabilidade corporativa. Nossa amostra foi selecionada com base nos *rankings* das maiores multinacionais das indústrias de computadores e semicondutores em 2023, de acordo com as revistas *Fortune* e *Forbes*. **Principais Resultados:** Considerando a significativa produção de insumos e bens, receita e geração de resíduos nessas indústrias, tínhamos a expectativa de que preocupações ligadas à sustentabilidade, como mudanças climáticas e redução da pegada de carbono, aparecessem em suas agendas. Nossa análise identificou as principais iniciativas alinhadas aos princípios da economia circular, como reutilização, redução e reciclagem de materiais, recursos e produtos, e comparou os padrões observados na amostra. **Relevância / Originalidade:** Nossos resultados são relevantes para entender as estratégias das empresas multinacionais e como elas lidam com a pressão de melhorar o uso de recursos de forma eficiente, por meio da abordagem da economia circular. **Contribuições Teóricas / Metodológicas:** Identificamos como as empresas multinacionais de uma mesma indústria abordam iniciativas de economia circular mediante uma análise detalhada de seus relatórios de sustentabilidade. **Contribuições Sociais / Gerenciais:** Com base em iniciativas bem-sucedidas, propomos ações sustentáveis que outras empresas possam explorar.

Palavras-chave: Economia Circular, Eletrônicos, Reportes de Sustentabilidade.

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INTRODUCTION

This research seeks to investigate how multinational companies (MNCs) are dealing with sustainability issues in their activities and verify whether they develop activities related to the circular economy (CE) and what they are.

Given the increasing scrutiny of corporate actions' societal and environmental impacts, more companies are allocating resources to sustainable activities to enhance their reputation with national and international stakeholders. Previous studies indicate that corporate social responsibility (CSR) activities help companies improve their image, win customers (Kim et al., 2020), and bring social legitimacy (Campbell et al., 2012).

However, within the international business (IB) literature, we found few studies on adopting sustainable strategies according to the CE assumptions. Most academic articles appear in publications on operations, supply chain management (SCM), or the environmental knowledge fields; however, this subject hardly appears in IB. Climate change is a global challenge, posing many risks for businesses. Considering the pervasive impact of MNCs on IB, it is important to understand how multinationals are adapting the system-wide framework of the CE to their specific situation. This research goes beyond examining how MNCs can reduce the generation of waste and investigating what they are doing to minimize their footprint and if and how they are addressing circularity, which is considered an important task from the multinational perspective (Montiel et al., 2021).

The segment choice was driven by its significant volume and revenue, along with stakeholder concerns about e-waste. E-waste, containing toxic substances like mercury, which may damage the human brain and/or the nervous coordination system, poses serious health and environmental hazards. Additionally, e-waste is the fastest-growing household waste stream globally due to the rapid consumption of short-lived electrical and electronic equipment with limited repair options.

According to the United Nations Global E-waste Monitor 2020 (Forti et al., 2020), 53.6 million tons of e-waste were generated worldwide in 2019 (a 21% increase in 5 years), with a projected 74 million tons by 2030. In addition, only 17.4% of the e-waste generated in 2019 was collected and recycled. Gold, silver, copper, platinum, and other high-value recoverable materials, conservatively valued at US$57 billion, were mostly dumped or burned rather than collected for treatment and reuse.

More recently, the United Nations Sustainable Development Goals Report 2022 indicates that most of the world's electronic waste is not being safely managed. E-waste collection rates are significantly higher in high-income countries compared to low- and middle-income countries, which indicates a potentially more harmful situation for the poorest (United Nations, 2022).

In this scenario, the CE approach offers a possibility of solving the global problem of waste and leftovers of electronic products since it is based on the premise of using product waste (outputs of an industry's value chain) as inputs for new production processes, whether in the same industry or different industries.

Considering the gap found in the literature related to CE issues from the standpoint of IB, this research will center on the context of MNCs in the electronics sector. Therefore, the research question proposed is: "How are electronics sector MNCs addressing sustainability issues with a focus on the CE?" The CE framework will be used to investigate to what extent companies have been able to relate and prioritize their actions and their impacts on the specific challenges.

This research aims to investigate how MNCs are dealing with sustainability issues in their activities and verify whether they develop activities related to the CE.

We performed a systematic review of 43 corporate sustainability reports in the computers and semiconductor industries, selected based on the largest multinationals in the electronics sector ranking in 2023, according to *Fortune* and *Forbes* magazines. Based on the information available in the McKinsey Global Institute (2022) database, we estimated that the global trade of products in the sectors of the firms that are the focus of our analysis was approximately US$1.8 Tri in 2022. We considered the global trade data of the following segments within the electronics sector: laptops, US$194 Bi; computer units, US$100 Bi; storage units for computers, US$77 Bi; parts and accessories for computers, US$157 Bi; semiconductor media storage devices, US$46 Bi; chips, processors, and controllers, US$541 Bi; chips memories,

US$241 Bi; and other chips, US$408 Bi. The sum of the reported revenue of all companies included in our analysis is approximately US$ 1.5 Tri, indicating that our sample represents the population of firms in the sectors studied.

We identified key initiatives related to the principles of the CE—reuse, reduction, and recycling of materials, resources, and products—and compared the patterns observed in the companies. Our findings are relevant to understanding MNCs' strategies and indicate different maturity levels among them. Most of them publish sustainability reports (95%), and 49% mention CE-related topics. In terms of standardization, 72% follow the Global Reporting Initiative (GRI), 79% the Sustainability Accounting Standards Board (SASB), and 63% the Task Force on Climate-Related Financial Disclosures (TCFD).

The main CE activities include zero-waste workplaces, recycling, reuse, packaging reduction, and waste management strategies.

Regarding the category "Reduce," the most executed activities are decreasing exposure to chemicals, eliminating plastics in packages, improving product energy efficiency, extending product lifespan, and reducing carbon footprint. The most executed activities of "Reuse" are reuse products or materials and reuse packaging. The most executed activities of "Recycle" are recycle materials, recycle materials in packages, and recycle waste.

In general, the activities most executed are reducing energy usage, reducing carbon footprint, and recycling materials. The most executed practices are related to the "Reduce" category; the categories "Reuse" and "Recycle" are still less developed.

Considering the extensive impact of MNCs on IB, it is essential to understand how they are adapting the system-wide framework of the CE to their specific situation. The paper's main contributions rely on a detailed analysis of how MNCs from a relevant sector are approaching CE initiatives and revealing different levels of maturity among them. We compile and analyze sustainable actions that can be explored by practitioners from diverse companies. At the end of the manuscript, we suggest a future research agenda.

Our article is structured as follows. In the first section, we provide a theoretical background and the concepts of sustainability and sustainable development, corporate responsibility, CE, and the R-principles (Reduce, Reuse, and Recycle). Next, in the methodology section, we describe our research strategy, data collection, and analytic approach. In the following section, we present our findings and discuss potential implications and the conclusions we made from our study. Finally, we address the limitations and possible future research.

1. LITERATURE REVIEW

Following Korhonen et al. (2018), this paper considers the concept of CE from the perspective of scientific research on sustainable development.

1.1 Sustainability and sustainable development

In historical terms, discussions about environmental problems and limits of nature's resources can be traced back to the Stockholm Conference (1972), and the broad concept of sustainable development was widely discussed in the early 1980s. However, it has not been emphasized in the international agenda until the publication of the report *Our Common Future* in 1987, by the World Commission on Environment and Development. Sustainable development was then defined as development that meets the needs of the present while not compromising the ability of future generations to meet their own needs (WCED, 1987). Later, in the early 1990s, Elkington (2012) introduced the triple bottom line (TBL) concept, which stated that business activity can simultaneously deliver financial, environmental, and social benefits. The objective was to stimulate change in corporate culture and highlight the importance and benefits of CSR and good environmental performance.

Other authors define sustainability as seeking social justice and environmental preservation (Jacobi, 2003), and state that development happens when people can have the possibility of choices, better living conditions, jobs, and justice (Veiga, 2005). There are also definitions of sustainability as concerned with what is necessary for communities and ecosystems to survive (Bellen, 2006) and discussions about humankind not surviving in the future if the planet's biodiversity and resources are destroyed (Kruglianskas & Pinsky, 2014).

Aligned with the purpose of our discussion, we adopt Elkington´s three-dimensional—economic, so-

cial, and environmental—original concept of sustainable development, which was created with the objective of provoking "deeper thinking about capitalism and its future" (Elkington, 2018, p. 4) and replacing the single bottom line paradigm, and its trade-off mindset. It is naturally related to the broader company role discussion—which goes beyond satisfying their shareholders—and to the CSR concept.

1.2 Corporate social responsibility

There is a growing discussion about corporations' roles and responsibilities in the socioeconomic system to achieve the goals of greater social justice and environmental sustainability. This topic is particularly important in the IB arena, considering the broad impact of MNCs.

Undoubtedly, companies must rethink their relationship with society and analyze CSR strategically; however, previous research has shown that multinationals still tend to develop these activities due to external pressures and do not include them in their strategies (Husted & Allen, 2006). In fact, despite the pressure in the world for companies to solve social, environmental, and ethical problems, they can deal with these problems reactively or proactively (Kolk, 2016). For some companies, CSR can lead to better financial results and competitive advantage; for others, CSR is strategic; for still others, it is not important (Husted & Allen, 2006). Such different approaches are reflected in the level of transparency and thoroughness of the information about CSR practices that companies report. In the following section, we explore the most adopted reporting standards.

1.3 Sustainability, corporate social responsibility, or environmental social governance reporting

An increasing number of large companies publish annual CSR reports, enhancing transparency and informing stakeholders about their sustainability strategies. These reports reflect corporate responsibility approaches and are increasingly being used by scholars as a data source (Stewart & Niero, 2018).

For instance, Sihvonen and Partanen (2017) used content analysis to review 43 CSR reports in the Information and Communication Technology (ICT) sector, searching for CE-related activities present at companies. Their results showed that most ICT companies in their sample were not yet actively engaged with reuse activities in terms of repair, refurbishment, or remanufacturing alternatives.

They also suggest a positive association between maturity in publishing quantitative environmental targets for products and the adoption of practices such as life cycle thinking, considering product durability, and remanufacturing.

In this study, we consider the terms sustainability, CSR, and ESG as interchangeable—despite representing different concepts—when referring to CSR reports. We focused on reporting standards and reported information rather than on the terms—sustainability, CSR, or ESG report—used by the companies in our sample. We also argue, in line with Sihvonen and Partanen (2017), and Stewart and Niero (2018), that CSR reports are a sound and reliable data source to investigate sustainability-related activities implemented by companies.

The most used sustainability, CSR, or ESG reporting standards are GRI, SASB, and TCFD. We provide a brief description of each standard:

- GRI: The GRI is an international, independent organization, headquartered in Amsterdam, the Netherlands. It provides the world's most widely used standards for sustainability reporting. The GRI standards were developed to be a global common language for businesses and other organizations to communicate and take responsibility for their impacts on the economy, environment, and society, including those on human rights. There are three series of standards: universal (for all organizations), sector (specific to sectors), and topic standards (for specific information on material topics), which can be used in a modular way, to prepare a complete sustainability report or, in parts, to report information for specific users or purposes (Global Reporting Initiative, 2022);
- SASB: SASB standards are designed to communicate with users whose primary objective is to improve economic decisions. These standards identify the sustainability information that is financially material to understanding how an organization creates enterprise value in the short, medium, and long term. In this sense, they are broader than pure financial reporting and narrower than sustainability reporting, which records the significant

impacts not captured by enterprise value, such as those that an organization has on the economy, environment, and people (SASB, 2022);

- TCFD was created by the Financial Stability Board (FSB) to develop recommendations about the information that should be disclosed by companies aimed at investors, lenders, and insurance underwriters who need to assess and price risks related to climate change. The recommendations are structured around governance, strategy, risk management, metrics, and targets and are supported by 11 recommended disclosures that build out a framework of information to support better capital allocation (TCFD, 2022).

Building on the previous theoretical concepts, Figure 1 illustrates how the scopes of these widely used reporting standards are interrelated.

In the following sections, we discuss the CE theory and its principles and clarify the difference between CE and reverse flows of supply chain management.

1.4 Differentiating circular economy from reverse flows of supply chain management

The ecological foundation of the CE involves restructuring material flows to balance resource use with the ecosystem's capacity. Unlike the traditional linear model, which generates excessive waste, CE aims to reduce resource shortages and pollution by ensuring waste does not exceed the ecosystem's ability to manage it (Yong, 2007).

According to Yong (2007), conversely, in the CE, such problems are approached from the perspective of reducing the material flow and balancing it between the ecosystem and the socioeconomic system. In other words, material flow changes to a circular approach (from resources to products and to wastes, and wastes translate to new resources) and efficiency of resource utilization is increased, and emissions are reduced. This is why the CE is accepted as a model for changing to a sustainable production and consumption pattern.

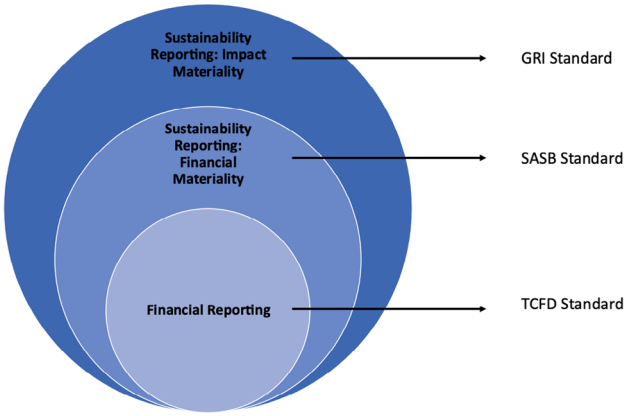

Figure 1. Scope of the sustainability reporting standards.

Yong (2007) states that another important remark to make about CE is its economic basis. The CE stresses the need to take material circulation and its supply–demand relationship into account as endogenic factors to economic growth (in addition to capital and labor circulation and their supply–demand relationships). This theoretical principle makes environmental and scarcity costs for the sustainable use of natural resources internalized into the full costs of socioeconomic activities, thereby encouraging resource-saving and pollution mitigation.

In the supply chain management literature, reverse flows are associated with terms such as sustainable supply chain management (SSCM), green supply chain management (GSCM), and closed-loop supply chain (CLSC) (Gurtu et al., 2015; Schenkel et al., 2015). SSCM refers to the integration of sustainable goals into a supply chain (Roy et al., 2018) and is associated with governance and social responsibility. GSCM is related to the integration of environmental thinking throughout the supply chain (Fang & Zhang, 2018; Malviya & Kant, 2015) and a theoretical approach to reducing negative environmental impacts in a supply chain (Batista et al., 2018; Jayaram & Avittathur, 2015). Both SSCM and GSCM are poorly developed as theories and are recognized in reverse logistics (RL) or CE practices (Viegas et al., 2019). At this point, it is important to distinguish these two concepts, as a superficial interpretation of CE might mistakenly lead readers to think that it is only about refreshing recycling schemes and reverse supply chains. At the same time, it, in fact, requires an actual systemic change (Webster, 2013). The concept of CE is broader than that of RL, as shown in Table 1.

Although the CE concept is not new, many conceptualizations coexist, as shown by Kirchherr et al. (2017) in their analysis of 114 CE definitions from academic and gray literature. The authors suggest that the concept of CE is constructed on a set of R-principles, in a systemic perspective, at all economic levels.

Table 1. Reverse logistics (RL)×circular economy (CE).

Reverse logistics	Circular economy
• Recovery and redemption of the value of goods, considered useless by the consumer, or whose functional characteristics prevent their proper or safe use (Agrawal et al., 2015). • Practices involve reuse, repair, and remanufacturing (Viegas et al., 2019). • Does not necessarily involve closed loops. • Focused on business processes. • It associates environmental and financial revenues but does not necessarily bring social benefits (Lai et al., 2013). • Limited version of CE (Geisendorf & Pietrulla, 2018).	• Also associated with closed-loop supply chains (CLSCs). • The main premise is to avoid waste, with the reduction, reuse, and recycling of resources in a supply chain through cleaner production principles and the extended use of value instead of value exchange. • It seeks to promote a win-win situation in economic, social, and environmental aspects (Genovese et al., 2017). • It fits at a deeper level than RL, resonating with resource/energy recirculation, multilevel approach, and ways in which society innovates and re-signifies new ways of using goods.

That means materials should first be recovered for reuse, refurbishment, and repair, then for remanufacturing, and only later for raw material utilization, which is the focus of traditional recycling (Korhonen et al., 2018).

In the following section, we discuss the R-principles of the CE concept and how circular business models can generate value.

1.5 Circular business models, value creation, and the R-principles (reduce, reuse, and recycle)

Circular business models contrast with linear business models because they represent "a set of strategic decisions designed to preserve the embedded environmental and economic value of a product or service into the system" (Centobelli et al., 2020, p. 1740), while in linear models, the value of the product or service is lost after use. Circular business models are designed to allow materials to return safely to the environment and value is created through closed-loop or circular systems implemented across the entire value chain, which focus on intentional restoration and regeneration (Ellen MacArthur Foundation, 2022). A circular business model can create markets for refurbished products, reusable components, and recycled raw materials. Value is generated through the recovery, repair, refurbishment, and resale of items, which can then be transferred to other users (Dragomir & Duţescu, 2022).

This approach requires firms to develop capabilities and resources to incorporate environmentally friendly practices into their strategy. Handling waste requires practices beyond recycling, which is a "last resource" after reducing and reusing materials. The 3Rs (Reduce, Reuse, and Recycle) form an environmental strategy for firms that can impact business performance (Ioannidis et al., 2021).

The 3Rs have a huge applicability to energy, water, and waste practices executed by firms, and they can influence the financial performance of companies (profitability and efficiency). Applying the 3R principles can protect the environment and improve the efficiency of using resources by companies. It can promote the transition between the linear economic growth model and the circular model (Ioannidis et al., 2021). Companies need to reduce the resource consumption of their production, reuse and redistribute used materials to enhance their use, and recycle resources to create jobs (in new industries of recycling) and socioeconomic improvements for the population (Goyal et al., 2018).

Furthermore, the term "reduce" is related to the lower waste generated through less consumption (Papa, 2015). Regarding "reuse," firms benefit from this action because it needs fewer resources, increases efficiency, and reduces costs; reusing can contribute to reducing (Ioannidis et al., 2021). The reuse process does not need the reprocessing of materials to create new products. To reuse is to take used products, recover them, and restart their use (Rizos et al., 2017). The term "recycle" means the transformation of organic materials into new products, and it is used in areas of water and waste efficiency (Ioannidis et al., 2021). It is a traditional way of developing the CE because it values existing products and avoids using virgin materials (Rizos et al., 2017).

2. METHOD

2.1 Research strategy and sample selection

In the social sciences, qualitative research is developed to allow researchers to study social and cultural phenomena in organizations (Myers, 2013).

We performed documental research on the largest (by revenue) MNCs in two specific industries of the electronics sector, the major e-waste producers. Documental research works from existing data, documents with different purposes (Gil, 2010). Social facts are registered in newspapers, magazines, and other media (Richardson, 2007), such as websites, for example.

We chose our sample in a purposeful manner with the objective of facilitating the investigation of the research question in our qualitative study. Since our research aims to investigate the adoption of sustainable strategies according to CE in the international context, we intentionally selected the largest MNCs in the electronics sector.

The choice of sector was driven by its substantial volume and revenue, and stakeholder concerns about e-waste, the fastest-growing household waste stream globally. This growth is driven by the rapid consumption of short-lived electrical and electronic equipment with limited repair options. This scenario appeared highly promising for providing insights into adopting CE principles.

Purposeful sampling is a non-random sampling technique in which researchers intentionally select participants, cases, or data sources that are most relevant to their study objectives. This method is widely used in qualitative research to ensure rich, in-depth insights by focusing on individuals or groups with specific characteristics, experiences, or expertise (Patton, 2015).

Data collection was based on the ranking of the 1,000 largest American companies (by revenue) in 2023, published by *Fortune* magazine. It resulted in an initial sample of 26 companies in the "Semiconductors and Other Electronic Components" industry and 12 companies operating in the "Computers and Office Equipment" industry, as shown in Tables 2 and 3.

We cross-referenced the list of 38 companies in the *Fortune* 1,000 US Companies—2023 Version—which only considers companies headquartered in the United States—with the 20 largest technology companies in 2023, according to *Forbes* magazine (Table 4). This procedure ensured that no large MNCs in the selected industries were neglected, regardless of their country of origin. Next, we identified five additional MNCs belonging to the two analyzed industries: the South Korean Samsung and the Japanese Sony Corporation—in the Computers and Office Equipment Industry—and the Taiwanese Taiwan Semiconductor Manufacturing Co., South Korea's SK Hynix, and the Dutch ASML Holding, in the semicon-

Table 2. Industry: Semiconductors and Other Electronic Components.

#	Rank *Fortune*	Company	Revenue US$ million
1	62	Intel	US$63.054
2	98	Qualcomm	US$44.200
3	121	Jabil	US$33.478
4	123	Broadcom	US$33.203
5	136	Micron Technology	US$30.758
6	152	Nvidia	US$26.974
7	155	Applied Materials	US$25.785
8	167	Advanced Micro Devices	US$23.601
9	200	Texas Instruments	US$20.028
10	240	Lam Research	US$17.227
11	344	Analog Devices	US$12.014
12	416	KLA	US$9.212
13	454	ON Semiconductor	US$8.326
14	471	Sanmina	US$7.891
15	508	Amkor Technology	US$7.092
16	522	Microchip Technology	US$6.821
17	580	Marvell Technology	US$5.920
18	605	Skyworks Solutions	US$5.486
19	676	Qorvo	US$4.646
20	769	Plexus	US$3.811
21	814	MKS Instruments	US$3.547
22	822	Vishay Intertechnology	US$3.497
23	848	Coherent	US$3.317
24	855	Entegris	US$3.282
25	872	Teradyne	US$3.155
26	909	Benchmark Electronics	US$2.886

Source: Prepared by the authors based on *Fortune* (2023).

Table 3. Industry: Computers and Office Equipment.

#	Rank *Fortune*	Company	Revenue US$ million
1	4	Apple	US$394.328
2	34	Dell Technologies	US$102.301
3	63	HP	US$62.983
4	143	Hewlett Packard Enterprise	US$28.496
5	221	Western Digital	US$18.793
6	44	NCR	US$7.844
7	505	Xerox Holdings	US$7.107
8	555	NetApp	US$6.318
9	636	Super Micro Computer	US$5.196
10	815	Pitney Bowes	US$3.538
11	829	Diebold Nixdorf	US$3.461
12	933	Pure Storage	US$2.753

Source: Prepared by the authors based on *Fortune* (2023).

ductor and other electronic components segment. Considering their relevance, the five companies were added to our initial sample, resulting in a final analysis of 43 companies.

2.2 Data collection and analysis

We accessed the websites of the 43 selected companies and mapped the following information in an Excel file: headquarters' location (home country), presence or not in Brazil, and whether a sustainability report was published. If so, we downloaded the 2023 report version and coded the content individually. Aligned with the research question and the deductive approach to answering it, we performed theoretical coding (Saldaña, 2013) and analyzed each sustainability report with codes that emerged from theory.

The MNCs were divided into three subsets, and each researcher analyzed and classified the practices reported for one subset.

For every single report, we identified whether any reporting standard was used, whether CE and RL activities were mentioned, and what were the main sustainability-related activities conducted.

Next, we classified the activities executed by each company into three categories: Reduce, Reuse, and Recycle, following the 3R´s literature. For each R, we conducted the process of pre-analysis, exploration of the materials, treatment of the results with posterior inferences and interpretations, and joint decision by the three authors regarding the classification of the practices for which there was no initial consensus. All data were transcribed to an Excel file. Finally, we developed a table with the results.

RESULTS

The analysis of the data collected from the 43 largest MNCs in the Electronics sector (14 companies in the Computers and Office Equipment industry and 29 companies in the Semiconductors and Other Electronic Components industry) provided the following results:

- Home country: A total of 38 (88.4%) MNCs are headquartered in the United States (with subsidiaries and offices in other countries), 2 (4.6%) in South Korea, 1 (2.3%) in Taiwan, 1 (2.3%) in Japan, and 1 (2.3%) in the Netherlands;
- Presence in Brazil: A total of 18 (41.9%) companies are in Brazil;
- Reporting: A total of 41 (95%) companies publish a sustainability report. It is important to mention that two companies — NCR and Vishay Intertechnology (5%) — still have not published a sustainability report (both are related to the Semiconductors and Other Electronic Components segment);
- Standards used as reference: A total of 31 (72%) companies follow the GRI standard, 34 (79%) follow the SASB standard, and 27 (62.8%) follow the TCFD standard. Some companies adopt more than one standard in their report;
- Circularity and RL: A total of 21 (48.8%) companies explicitly mention the term circular economy, while five (11.6%) mention RL and related topics in their reports.

Companies' main CE activities include equipment collection, zero-waste workplaces, garbage reduction, recycling, reuse, packaging reduction and collection, using recyclable materials, reducing product environmental impact, product returns, creating longer-lasting products, material recovery, and waste management strategies.

Table 5 presents the classification of the activities of the companies from both segments (Computers and Office Equipment and Semiconductors and Other Electronic Components) among the 3R´s categories.

Table 4. The 20 largest technology companies in 2023 according to *Forbes*.

#	Company	Origin	Sales (US$ billion)	Industry*	Cited by *Fortune*?	Reason
1	Alphabet Inc.	USA	US$282.8	Other		
2	Microsoft Co.	USA	US$207.6	Other		
3	Apple Inc.	USA	US$385.1	C & OE	Yes	
4	Samsung Group	South Korea	US$220.1	C & OE	No	Origin
5	Meta Platforms	USA	US$117.3	Other		
6	Tencent Holdings Ltd.	China	US$82.4	Other		
7	Taiwan Semiconductor Mfg. Co. (TSMC)	Taiwan	US$75	S & OEC	No	Origin
8	Sony Corporation	Japan	US$85.2	C & OE	No	Origin
9	Oracle Corporation	USA	US$48	Other		
10	Cisco Systems Inc.	USA	US$53.2	Other		
11	Hon Hai Precision Industry Co.	Taiwan	US$222.3	Other		
12	Broadcom Limited	USA	US$34.4	S & OEC	Yes	
13	Accenture PLC	Ireland	US$63.1	Other		
14	IBM	USA	US$60.6	Other		
15	Qualcomm Inc.	USA	US$41.1	S & OEC	Yes	
16	SAP AG	Germany	US$32.5	Other		
17	Dell Technologies Inc.	USA	US$101.6	C & OE	Yes	
18	ASML Holding	Netherlands	€ 25.4	S & OEC	No	Origin
19	Nvidia Corporation	USA	US$27	S & OEC	Yes	
20	SK Hynix Inc.	South Korea	US$34.5	S & OEC	No	Origin

*Industries' labels: C & OE: Computers and Office Equipment; S & OEC: Semiconductors and Other Electronic Components; Other: industries out of the scope of our analysis (includes Software, Internet Services, Social Media, Network and Communications Solutions, IT Services, Electronic Products Manufacturing, Management Consulting, IT, and Outsourcing).
Source: Prepared by the authors based on *Forbes* (2023) and *Fortune* (2023).

We verify that 11 companies in the Computers and Office Equipment segment are engaged in the three R´s activities, while 24 companies in the Semiconductor and Other Electronic Components segment report practices in the three categories. The Reuse category appears at a lower level than the others. The two companies where "not applicable" (N/A) appears did not publish their sustainability reports.

Tables 6 and 7 go deeper into the three categories, identifying specific activities for each company that performs them.

According to Table 6, within the "Reduce" category, which includes the greatest number of activities, companies in the Computers and Office Equipment sector most frequently engage in actions such as reducing exposure to chemicals or hazardous substances, eliminating plastics in packaging or transitioning to more sustainable alternatives, improving product energy efficiency, minimizing emissions, reducing environmental impacts, reducing water impact, achieving zero waste to landfill, and decreasing overall energy and waste usage. In contrast, organizations in the Semiconductors and Other Electronic Components sector primarily focus on activities such as enhancing product energy efficiency, extending product lifespan, reducing emissions, minimizing environmental footprint, reducing water impact and waste, as well as utilizing clean energy and lowering overall energy consumption.

In the "Reuse" category, the most frequently observed activities in the Computers and Office Equipment sector are the reuse of products or materials

Table 5. Categorization of companies per segment and kind of action.

Segment	Company	Reduce	Reuse	Recycle
Computers and Office Equipment	Apple	✓	✓	✓
	Dell Technologies	✓	✓	✓
	HP	✓	✓	✓
	Hewlett Packard Enterprise	✓	✓	✓
	Western Digital	✓		✓
	NCR	N/A	N/A	N/A
	Xerox	✓	✓	✓
	Net App	✓	✓	✓
	Diebold Nixdorf	✓	✓	✓
	Pitney Bowes	✓	✓	✓
	Super Micro Computer	✓		
	Pure Storage	✓	✓	✓
	Samsung Electronics	✓	✓	✓
	Sony Corporation	✓	✓	✓
Semiconductors and Other Electronic Components	Intel	✓	✓	✓
	Jabil	✓	✓	✓
	Micron Technology	✓	✓	✓
	KLA	✓	✓	✓
	Microchip Technology	✓		✓
	Skyworks Solutions	✓	✓	✓
	Marvell Technology		✓	✓
	Teradyne	✓	✓	✓
	Benchmark Electronics	✓	✓	✓
	Taiwan Semiconductor	✓	✓	✓
	SK Hynix	✓	✓	✓
	Qualcomm	✓	✓	✓
	Nvidia	✓	✓	✓
	Applied Materials	✓	✓	✓
	Texas Instruments	✓	✓	✓
	Advanced Micro Devices	✓	✓	✓
	Lam Research	✓	✓	✓
	Analog Devices	✓	✓	✓
	Sanmina	✓	✓	✓
	ON Semiconductor	✓	✓	✓
Semiconductors and Other Electronic Components	Amkar Technology	✓	✓	✓
	Qorvo	✓	✓	✓
	Broadcom	✓	✓	✓
	Plexus	✓	✓	✓
	Vishay Intertechnology	N/A	N/A	N/A
	ASML	✓	✓	✓
	Coherent	✓		✓
	MKS Instruments	✓		
	Entegris	✓	✓	✓

Table 6. Categorization of companies per segment and specific actions: Computers and Office Equipment.

Companies/companies' actions	Reduce											Reuse									Recycle								
	Carbon footprint/Pollution	Waste	Water usage	Energy usage	Plastic usage	Preterm disposal	Consumption of virgin materials	Exposure to chemicals or hazardous materials	Reduce/avoid non-compliance materials	Reduce/avoid materials from conflict zones	Develop sustainable products	Material recovery	Recover rare magnets	Repairability of products or parts	Products or materials	Use materials from other industries	Regenerate resources	Remanufacturing	Packaging	Water	Refurbishment	Materials	Metals	Technology	Plastic	Hazardous waste	Materials in packages	Waste	Use recycled materials	Water
Apple	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓								✓	✓							
Dell Technologies	✓	✓	✓	✓	✓								✓		✓	✓						✓		✓	✓					
HP	✓			✓	✓										✓							✓								
Hewlett Packard Enterprise	✓		✓		✓										✓				✓								✓	✓		
Western Digital	✓	✓		✓	✓																	✓					✓			
NCR																														
Xerox	✓	✓		✓	✓	✓					✓				✓			✓				✓								
Net App					✓		✓	✓							✓							✓								
Diebold Nixdorf		✓	✓	✓				✓			✓				✓				✓			✓						✓	✓	
Pitney Bowes					✓			✓				✓			✓					✓		✓						✓	✓	
Super Micro Computer				✓																										
Sony Corporation	✓	✓		✓	✓		✓					✓							✓	✓		✓	✓		✓			✓	✓	
Pure Storage		✓		✓				✓			✓				✓							✓								
Samsung Electronics	✓	✓	✓	✓							✓									✓		✓			✓		✓	✓	✓	✓

Source: Elaborated by the authors (2024).

and packaging. For the Semiconductors and Other Electronic Components sector, the primary activities cited include reusing products or materials and water.

In the "Recycle" category, the most commonly cited activities by companies in both sectors are recycling materials, packaging materials, and waste. In the end of the work, 43 companies were researched and they published 41 sustainability reports (2 companies didn't publish reports) — see the Appendix 1 to check this information.

3. DISCUSSION

In general, the most implemented activities by companies regarding the 3Rs focus on reducing energy consumption and CO_2 emissions, and recycling materials. We can conclude that the majority of practices align with the "Reduce" category, as companies continue to prioritize minimizing resource usage in their production processes. However, the "Reuse" and "Recycle" categories remain less developed in comparison. Despite this, there is still significant potential for companies to strengthen their efforts in the "Reduce" category while also directing more attention to enhancing activities within the "Reuse" and "Recycle" categories.

Among the companies included in this study, Sony stands out as the leader, implementing 13 of the 3R activities observed. Apple, Samsung, Intel, and Taiwan Semiconductors follow closely, each executing 12 activities, while Dell implements 11. Sony, Apple, Samsung, and Dell are part of the Computers and Office Equipment sector, while Intel and Taiwan Semiconductors belong to the Semiconductors and Other Electronic Components industry.

We also verified significant differences in the level of maturity of the companies regarding CE. The 21 MNCs that explicitly reported performing activities related to CE are Apple, Dell, HP, Hewlett Packard Enterprise, Sony Corporation, Intel, Jabil, Samsung, Micron Technology, Taiwan Semiconductor, Western Digital, Xerox, Pitney Bowes, SK Hynix, Applied Materials, Advanced Micro Devices, Analog Devices, Plexus, Coherent, ASML, and Entegris.

Based on the findings, the companies from both segments develop more activities related to the Re-

Table 7. Categorization of companies per segment and specific actions: Semiconductors and Other Electronic Components.

Companies/companies' actions	Reduce											Reuse									Recycle							
	Carbon footprint/Pollution	Waste	Water usage	Energy usage	Plastic usage	Preterm disposal	Consumption of virgin materials	Exposure to chemicals or hazardous materials	Reduce/avoid non-compliance materials	Reduce/avoid materials from conflict zones	Develop sustainable products	Material recovery	Recover rare magnets	Repairability of products or parts	Products or materials	Use materials from other industries	Regenerate resources	Remanufacturing	Packaging	Water	Refurbishment	Materials	Metals	Technology	Plastic	Hazardous waste	Materials in packages	Waste	Use recycled materials	Water
Intel	✓	✓	✓	✓	✓						✓	✓			✓		✓			✓		✓				✓				
Jabil	✓		✓	✓	✓																					✓	✓			
Micron Technology	✓	✓	✓	✓							✓				✓					✓								✓		✓
Broadcom	✓																			✓								✓		
KLA		✓	✓		✓						✓																	✓		✓
Microchip Technology	✓		✓	✓																		✓	✓				✓	✓	✓	
Skyworks Solutions		✓	✓																	✓								✓		
Marvell Technology												✓										✓								
Teradyne	✓	✓		✓							✓			✓							✓	✓						✓		
Benchmark Electronics	✓	✓	✓	✓											✓					✓		✓				✓			✓	✓
Taiwan Semiconductor	✓	✓	✓	✓				✓	✓						✓	✓				✓		✓						✓		✓
SK Hynix	✓	✓	✓	✓																✓		✓			✓	✓		✓		
Qualcomm	✓		✓	✓				✓		✓	✓									✓								✓		
Nvidia	✓	✓	✓	✓				✓							✓												✓	✓		
Applied Materials		✓			✓		✓				✓	✓		✓	✓			✓			✓	✓								
Texas Instruments	✓	✓	✓	✓					✓				✓		✓							✓							✓	
Advanced Micro Devices	✓		✓	✓	✓						✓									✓						✓			✓	
Lam Research	✓			✓							✓				✓					✓			✓		✓					✓
Analog Devices	✓	✓	✓	✓							✓				✓							✓			✓					
Sanmina	✓																			✓										✓
ON Semiconductor	✓	✓		✓					✓						✓							✓			✓		✓			✓
Amkar Technology	✓	✓	✓																	✓		✓								
Qorvo	✓				✓			✓			✓								✓											✓
Plexus	✓		✓	✓								✓										✓								
Vishay Intertechnology																														
ASML	✓	✓		✓								✓		✓			✓				✓	✓						✓		
Coherent		✓								✓												✓	✓					✓		
MKS Instruments	✓	✓	✓					✓																						
Entegris		✓	✓	✓							✓									✓						✓				✓

Source: Elaborated by the authors (2024).

duce category, followed by Recycle and Reuse. It was not an intuitive discovery, given that when thinking about CE theory, the expected actions are, in order, Reduce, Reuse, and Recycle – as a sequence, which has not occurred.

3.1 Successful initiatives

The sustainability reports provided relevant cases and insights regarding how companies incorporate CE into their sustainability strategy.

MNCs are considered relevant players given their global influence and ability to deal with a range of issues in both home and host markets (Ghauri et al., 2022). In 2019, Apple participated in the United Nations Environment Assembly and conducted bilateral discussions with several countries to advocate for policies that enable a CE and bold action on climate. Apple´s approach to achieving circularity can be summarized in three pillars: sourcing and efficiency, product longevity, and collection and recovery, aligned with Ioannidis et al. (2021).

Hewlett Packard Enterprise dedicates a separate report to its CE initiatives. The company states that "our circular economy approach drives more effective use of energy and materials and enables customers to manage their IT assets in a secure, compliant, and environmentally responsible manner," a definition supported by Dragomir and Duţescu (2022). The company shares indicators (including savings, productivity enhancement, new value capture, and environmental impact reduction enabled by CE activities) and details the methodology used to calculate key report values, as they invite customers to join the CE approach and offer a "suite of solutions that help create circularity within an organization."

Intel has incorporated CE in its long-term commitments, a positioning proposed by Kim et al. (2020). For the 2030 goal, the company aims to "achieve zero waste to landfill and implement circular economy strategies for at least 60% of our manufacturing waste streams in collaboration with our suppliers." In order to reach this and other goals related to CE, beyond internal initiatives, Intel engages with industry peers at the Open Compute Project (OCP) (a community formed by startups, academia, investors, and hyperscales that forges new technology norms, fostering an ecosystem where industry players collaborate in a safe framework, shaping a versatile and diverse supply chain) on sustainability as a new principle. The OCP circularity working group has published guidelines to share and educate member companies on circularity principles. While the supply chain disruptions in recent years are making circularity a business imperative in many sectors, practical implementations of these principles in the data center sector are rare. In this sense, joining alliances is essential to understand new demands better and help develop and have access to standard solutions.

3.2 Theoretical and practical implications

This study addresses a gap in the IB literature regarding MNCs' perspective on the CE approach. The proposed theoretical framework serves as a background to understanding the CE 3R´s categories and making their recognition in the sustainability reports possible. By focusing on a specific industry (electronics), we identified how the MNCs are addressing sustainability issues with a focus on the CE.

From a practical standpoint, this paper provides interesting insights into how MNCs' strategies are shaping the CE approach. We identified the most relevant Reduce, Reuse, and Recycle initiatives performed by the chosen sectors (Computers and Office Equipment and Semiconductors and Other Electronic Components). We offered a summary that can be used as a starting tool by practitioners.

Each experience delivers valuable insights into how an organization deals with the CE approach including implementation, stakeholders' involvement, alliances, measuring, and goals.

3.3 Limitations and future research

The first limitation of this study concerns the specific nature of the chosen sectors (Computers and Office Equipment and Semiconductors and Other Electronic Components), which prevents generalization to other segments.

Generalizations to small- and medium-sized companies are also challenging to make since multinationals have, due to their structure, more complex resources, and strategies, compatible with the organization size.

Finally, in the above limitations, we envision avenues for deepening studies related to sustainability and CE issues in other businesses, types of companies, and countries.

As an extension of this research, additional secondary data can be collected from other data sources, such as the media and other public information about the companies in the sample that operate in Brazil. The additional data can be used for triangulation (Creswell, 2013) and for further understanding on how the actions linked to the CE, described in the sustainability reports, are carried out, thus contributing to advancing our knowledge about the relationships between these companies and their stakeholders. This study, based on the case of MNCs, will contribute to the IB literature.

However, we remember that cultural, regulatory, economic, and infrastructure aspects vary according to each location and should be carefully analyzed before generalizing the results of this study to the context of other countries.

Based on limitations and research opportunities, we propose the following research questions: How are MNCs' subsidiaries dealing with CE principles and implementation? How can emerging technologies help improve CE efficiency? How are emerging countries' MNCs dealing with CE implementation, and which contextual challenges do they need to overcome? How are CE principles affecting global value chains? These are some of the topics that have arisen during the study.

4. CONCLUSION

This research examines how the electronics industry MNCs are addressing sustainability issues with a focus on CE. We analyzed their most recent sustainability report practices from the "Computers and Office Equipment" and "Semiconductors and Other Electronic Components" sectors, based on the *Fortune* 1,000 and *Forbes* rankings. The findings were categorized into three types of actions: Reduce, Reuse, and Recycle, the CE principles, as outlined in the theoretical section of the paper. Besides, we shared successful initiatives and highlighted our study´s theoretical and practical contributions, along with limitations and research opportunities.

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Appendix 1. The sustainable reports of the companies that participated in the research.

Company Name	Year	Report Name	Region	Sector
Advanced Micro Devices	2024	2022-2023 Corporate Responsibility Report AMD	USA	Semiconductor and Other Electronic Components
Amkor	2023	2022 ESG Report	USA	Semiconductor and Other Electronic Components
Analog Devices	2023	Analog Devices 2022 ESG Report	USA	Semiconductor and Other Electronic Components
Apple	2024	2023 Environmental Progress Report	USA	Computers and Office Equipment
Applied Materials	2023	Sustainability Report 2022	USA	Semiconductor and Other Electronic Components
ASML	2024	Sustainability Report 2023	Netherlands	Semiconductor and Other Electronic Components
Benchmark Eletrocnics	2024	2023 Sustainability Report	USA	Semiconductor and Other Electronic Components
Broadcom	2024	2023 Environmental, Social and Governance Report	USA	Semiconductor and Other Electronic Components
Coherent Corp	2024	Coherent ESG Report 2023	USA	Semiconductor and Other Electronic Components
Dell Technologies	2024	FY 23 Progress Made Real Report	USA	Computers and Office Equipment
Diebold Nixdorf Incorporated	2023	2022 Diebold Nixdorf ESG Report	USA	Computers and Office Equipment
Entegris	2023	Corporate Social Responsibiity Report	USA	Semiconductor and Other Electronic Components
Hewlett Packard Enterprise	2023	HPE Living Progress Report 2022	USA	Computers and Office Equipment
HP	2023	HP Go Beyond 2022: HP Sustainable Impact Report	USA	Computers and Office Equipment
Intel	2024	Corporate Responsibility Report	USA	Semiconductor and Other Electronic Components
Jabil	2024	Jabil Sustainability Report 2023	USA	Semiconductor and Other Electronic Components
KLA	2023	KLA Global Impact Report 2022	USA	Semiconductor and Other Electronic Components
Lam Research Corporation	2024	2023 Environmental, Social and Governance Report	USA	Semiconductor and Other Electronic Components
Marvell	2024	Marvell Advancing Technology for a Sustainable Future FY 2023	USA	Semiconductor and Other Electronic Components
Microchip Technology	2023	2022 Microchip Sustainability Report	USA	Semiconductor and Other Electronic Components
Micron Technology	2024	Micron Sustainability Report 2024	USA	Semiconductor and Other Electronic Components
MKS Instruments	2023	Environmental, Social, Governance Report 2023	USA	Semiconductor and Other Electronic Components

Continue...

Appendix 1. Continuation.

Company Name	Year	Report Name	Region	Sector
NetApp	2023	NetApp 2023 ESG Report	USA	Computers and Office Equipment
NVIDIA	2024	2023 NVIDIA Corporate Sustainability Report	USA	Semiconductor and Other Electronic Components
On Semiconductor	2024	2023 Sustainability Report	USA	Semiconductor and Other Electronic Components
Pitney Bowes Inc	2023	ESG Report 2022	USA	Computers and Office Equipment
Plexus	2023	Sustainability Report FY 2022	USA	Semiconductor and Other Electronic Components
Pure Storage Inc	2024	2023 ESG Report: Technology and Sustainability	USA	Computers and Office Equipment
Qorvo Inc	2024	We are Qorvo FY 23 Sustainability Report	USA	Semiconductor and Other Electronic Components
Qualcomm Technologies Inc	2023	Qualcomm Corporate Responsibility Report	USA	Semiconductor and Other Electronic Components
Samsung Electronics	2024	Samsung Electronics Sustainability Report 2023	South Korea	Computers and Office Equipment
Sanmina	2023	2022 Corporate Social Responsibility Report	USA	Semiconductor and Other Electronic Components
SK Hynix	2024	SK Hynix Sustainability Report 2023	South Korea	Semiconductor and Other Electronic Components
Skyworks Solutions	2023	Sustainability Report 2022	USA	Semiconductor and Other Electronic Components
Sony Corporation	2024	Sustainability Report 2023	Japan	Computers and Office Equipment
Supermicro	2024	2023 Green Computing Supermicro	USA	Computers and Office Equipment
Taiwan Semiconductor Mfg Co	2023	TSMC 2022 Sustainability Report	Taiwan	Semiconductor and Other Electronic Components
Teradyne	2024	Corporate Social Responsibility Report 2023	USA	Semiconductor and Other Electronic Components
Texas Instruments	2023	2022 Corporate Citizenship Report	USA	Semiconductor and Other Electronic Components
Western Digital	2023	Western Digital FY 2022 Sustainability Report	USA	Computers and Office Equipment
Xerox	2024	2023 Corporate Social Responsibility Report	USA	Computers and Office Equipment