European Journal of Sustainable Development (2023), **12**, 4, 339-354 ISSN: 2239-5938
Doi: 10.14207/ejsd.2023.v12n4p339

Green Growth and Technology: Is there a Relationship with Green Innovation?

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ABSTRACT

This study intends to analyze how the adoption of Green Innovation (GI) practices by companies of the industrial sector promotes the development of Green Technologies (GT) and Green Growth (GG) in Developed Countries (DC) and Emerging Countries (EC). The survey sample consisted of 8659 observations from DC industrial companies and 1958 observations from EC companies, from data collected from Thomson Reuters and the Organization for Economic Co-operation and Development (OECD). Structural Equation Modeling was used for variable relationship analysis. The results pointed out that, in DC, GI practices impacts positively the GT of the countries, but this does not occur with the GG, which are negatively affected by the adoption of GI practices by the companies. On the other hand, in EC, only environmental investments positively affected the development of GT in these countries. And in relation to the GG, the GI practices of Environmental Management and Environmental Policies positively influenced this growth. The survey results contribute to discussions on regional differences in the benefits of green innovation by companies in promoting sustainable development. In addition, it can contribute with possible paths for companies and governments in setting goals to achieve SDG-8, SDG-9 and SDG-10.

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Keywords: green innovation; green technology; green growth; SDG.

1. Introduction

The environmental impact of human activities has emerged as a pressing global concern for society. Lately, there have been a record of carbon dioxide emissions from fossil fuels. Additionally, from 1900 to 2018, the global average sea level increased by 20 centimeters, as well as the occurrences of heatwaves, wildfires, and air pollution. Furthermore, concentrations of major greenhouse effect gases have remained on the rise, and the average surface temperature of the Earth from 2017 to 2021 is among the highest ever recorded (Intergovernmental Panel on Climate Change – IPCC, 2021).

Events and regulations that have emerged over the years highlight the need for governments to adopt actions to reduce environmental impacts, such as the Montreal Protocol of 1987 (CFCs), or the Kyoto Protocol, created in the same year, which aimed to restrict carbon dioxide (CO_2) emissions. The concept of Sustainable Development was announced at the World Summit in Johannesburg in 2002, and the United Nations defined the Sustainable Development Goals (SDGs) in 2015.

In this context, the role of private companies in promoting the adoption of new management measures that consider green innovation and environmental regulations

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aligned with competitiveness (Borsatto & Amui, 2019) is also highlighted. The green business discourse announces a shift from the proposed course of conventional development, overcoming the companies' omission in a recent highly polluting past. Sensitized to environmental issues and signaling the beginning of an ideological transition process, they have incorporated ecological principles into their *modus operandi*, marking the beginning of a new phase based on environmental sustainability criteria (Layrargues, 2000). In line with this theme, Chen et al. (2006) proposed the notion of Green Innovation (GI), which is defined as the search, promotion, and development of ecological products, services, and processes that incorporate a certain degree of novelty (Chen et al., 2012). This concept involves innovative ideas that strive to offer environmentally friendly products or services throughout their entire lifecycle, from conception to disposal, without harming nature or the environment.

Although Green Innovation primarily seeks to enhance environmental sustainability, it would result in positive outcomes in various domains, including the economy and society, and serve as a source of competitive advantage for companies (Guinot et al., 2022). Consequently, associated with Green Innovation is Green Growth (GG), which, according to Bowen & Hepburn (2014), capture the idea of economic growth and the protection of natural capital.

Technology is often associated with innovation and economic growth. Academic literature has extensively explored the role of technological advancement in environmental performance, yielding results that indicate Green Technology (GT) as the basis for "Green Development" (Du & Li, 2019; Guo et al., 2021). Green Technology is understood as a broad category encompassing technologies that strive to maximize energy efficiency and environmental preservation (Guo et al., 2021), and innovations in this area have rapidly become a driving force for high-quality economic development by promoting the transformation of development methods and resource efficiency (Zhang & Li, 2020).

Considering this, and considering the relationship between innovation, technology, and growth, the present study seeks to answer the following question: How does the adoption of Green Innovation practices by private companies promote the development of Green Technologies and Green Growth in Developed and Developing Countries? To address this question, this research aims to examine how the adoption of Green Innovation practices by private companies promotes the development of Green Technologies and Green Growth in Developed and Developing Countries. To achieve this objective, structural equation modeling was conducted using data from large companies and indicators from their respective countries.

Considering the role of Green Innovation and Technology in the development of products and processes that generate fewer environmental, social, and economic damages, and consequently promote the green growth of countries, this research aims to contribute to a line of study that investigates the collaborative relationship between the private and public sectors in the pursuit of Sustainable Development. Furthermore, this research aims to contribute by verifying whether its results support the Sustainable Development Goals (SDGs), such as SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG

17 (Partnerships for the Goals) (IPEA, 2023), demonstrating possibilities for addressing societal issues.

2. Theoretical Review and Hypotheses

Innovation refers to a process that involves the utilization of creativity to develop and offer novel or improved solutions to meet consumer desires and needs (Kahn, 2018). Additionally, it can be seen as a transformative force that breaks the monotony of economic cycles and facilitates ongoing growth, closely intertwined with technological advancements (Varadarajan, 2018).

In this sense, Green Innovation (GI) is conceptualized as the improvement of products or processes regarding energy efficiency, waste recycling, green product design, pollution prevention, and corporate environmental management within the scope of environmental management (Chen et al., 2006). Furthermore, Green Innovation is a potential path to enhance environmental management performance to meet environmental regulations requirements and has consequently become one of the relevant strategic tools for the development of effective sustainable management.

In previous periods, investing in environmental practices was considered unnecessary. However, with the emergence of Sustainable Development Goals (SDGs), the establishment of stringent environmental regulations, and a growing global concern about Sustainable Development, the competition rules for companies have changed (Chen et al., 2012). Moreover, Green Innovation practices have become a response given by companies to customer demands, who are willing to pay more for sustainable products and require ecologically friendly products and services (Chen et al., 2012; Tang et al., 2018), as well as market demands, since Green Innovation practices contribute to improving performance and competitiveness of companies (Borsatto & Bazani, 2021; Schiederig et al., 2012). In this context, the concept of Green Growth emerges because of Green Innovation.

According to the OECD (2020), Green Growth (GG) shows whether a company's economic growth is becoming greener by using natural capital more efficiently. As an indicator, it measures progress towards a more sustainable and greener economy. Various definitions of Green Growth exist, which commonly encompass the concept of an expanding economy based on the value of goods and services, while simultaneously safeguarding natural assets and resources (Bowen & Hepburn, 2014). Another common aspect among these definitions is the mechanism to achieve Green Growth: the promise is that technological transformation and the substitution of production methods will improve the ecological efficiency of the economy, and that governments can accelerate this process through appropriate regulations and incentives (Hickel & Kallis, 2020). Therefore, there are studies investigating Green Growth and the factors that influence its progress, and one of the most common topics is Green Technology and how efforts directed in this direction, including technological innovation, environmentally related technological advancement, and green industrial development, can support Green Growth (Chen et al., 2018; Hickel & Kallis, 2020). In this regard, the following hypotheses are proposed:

- H_{1a}: Private companies' Green Innovation (GI) efforts positively impact Green Growth (GG) in Developed Countries (DC).

- H_{1b}: Green Innovation (VI) efforts by private companies positively impact Green Growth (GG) in Least Developed Countries (LDC).

Green Technology (GT) is an essential and inevitable choice for ensuring the sustainability of production and resources while also considering economic aspects. With the emergence of environmental values, as well as the need to maximize economic efficiency, have demanded a change in the *modus operandi* of organizations, creating space for Green Technology. Its value lies in the development of technological innovations that contribute to ecologically sound, stable, and long-lasting production, combining economic benefits with solutions to environmental problems (Chen, 2008; Chen & Chang, 2013; Zhang et al., 2020; Guo et al., 2021).

In 2011, the OECD recognized that Green Technology should go hand in hand with the development or growth of any social sector, and that Green Technologies are the best way to select and propose interventionist measures for environmentally balanced production (OECD, 2011). However, although technological innovations have solved many of the problems faced by humans, there are still environmental issues that they must effectively address, such as carbon emissions and global temperature rise, which severely restrict sustainable development. Therefore, as one of the main exploiters of natural resources, corporate motivation for Green Innovation and Green Technology plays a crucial role in global sustainable development. And to maximize their own economic benefits and achieve social goals, various countries formulate different policies to guide or incentivize companies to achieve energy conservation and emissions reduction, improving resource efficiency. Through the guidance of green policy practices, companies can improve their resource efficiency and achieve mutually beneficial development (Porter & Vanderlinde, 1995; Li et al., 2019).

Studies exploring the perspectives of companies and the public sector in the pursuit of sustainable development, as well as the relationship between these two parties regarding this matter, have become more popular (Zhang et al., 2022). And many of them, such as Borsatto & Amui (2019), confirm the existence of a positive relationship between government actions and a company's sustainability actions. However, depending on how these sustainability actions are measured, these effects can vary, and this relationship can be influenced by other factors such as company size, structure, degree of internationalization, and motivation to invest in green practices (Borsatto & Amui, 2019; Hong et al., 2021).

Nevertheless, the consensus seems to be that the role of the government in the process of building a sustainable ecosystem is primarily to motivate business innovation (Nemet, 2009), and that companies play a significant role in constructing a sustainable national system (Freire-Gibb, 2012).

Considering this, the following hypotheses arise:

- H_{2a}: Green Innovation (GI) efforts by private companies positively impact Green Technology (GT) in Developed Countries (DC).
- H_{2b}: Green Innovation (GI) efforts by private companies positively impact Green Technology (GT) in Least Developed Countries (LDC).

3. Methodology

3.1 Sample and Data Collection

Secondary data from different sources were used, containing consolidated information from 2015 to 2019 for countries belonging to the G7 economic groups (United States, Germany, France, Canada, Italy, Japan, and the United Kingdom) representing developed countries, and BRICS (Brazil, Russia, India, China, and South Africa) representing emerging economies. The data were compiled into a single database, including:

1. Data Stream database owned by Thomson Reuters for variables related to companies, containing information regarding their size and financial performance (Total Revenue, Total Assets, ROA, and ROE) and their investments in Green Innovation.
2. Innovation indicators in environmentally related technologies by country, provided by OECD.Stat.
3. Green Growth indicators by country, provided by OECD.Stat.

After consolidating the data, the variables that best represented investments in Green Innovation and the levels of Green Technology and Green Growth in countries were chosen. Moderating variables were also chosen. Only fully-informed companies were selected for the article's model completion, resulting in a final sample composed of 10613 companies.

3.2 Model's Variables

Considering that the objective of the study is to examine how the adoption of Innovative green practices by companies that promotes the development of Green Technologies and Green Growth in Developed and Least Developed Countries, Green Innovation, Green Technology, Green Growth, and Moderating Variables were used, which are detailed in Table 1.

Table 1. Summary of variables used

Variable	Acronym	Measuring Methods	Source	Authors
Green Innovation	EM	**Factor Analysis of dummy variables:** Environmental Management Team (EMT) Environmental Management Training (EMTR) Supply of Environmental Materials (SEM) Green Buildings (GB); Environmental Supply Chain Management (ESCM); ISO 14000	Thomson Reuters	Kim, (2015); Barla (2007); Gibson & Tierney (2011).
	EP	Resource Reduction Policy (RRP); Water Efficiency Policy (WEP); Energy Efficiency Policy (EEP); Sustainable Packaging Policy (SPP); Environmental Policy for the Supply Chain (EPSC);	Thomson Reuters	Alisik & Gal (2014); Fernandez-Feijoo, et al., (2014).

		Emissions Policy (EP); Employee Health Safety Policy (EHSP)		
	EI	Environmental Disputes (ED) Environmental Restoration Initiatives (ERI) Spending on Environmental Investments (SEI) Environmental Investment Initiatives (EII) Reduced Impact on Biodiversity (RIB)	Thomson Reuters	Kim, (2015); Barla (2007); Gibson & Tierney (2011); Alisik & Gal (2014); Fernandez-Feijoo, et al., (2014).
Green Technology	GT	**Factor Analysis of the variables:** Percentage of Development of Environmentally Related Technologies in Relative to All Technologies (%TEC1); Percentage of Relative Advantage in Development of Environmentally Related Technologies in Relative to All Technologies (PRADERT); Percentage of Diffusion of Technologies Related to the Environment in Relation to All Technologies (%TEC2); Percentage of International Collaboration in the Development of Technologies Related to the Environment Relative to Collaborations in All Technologies (%COLTEC); Propensity to Collaborate with Foreign Countries in the Development of Technologies Related to the Environment (PCFC)	OCDE	-
Green Growth	GG	**Factor Analysis of the variables:** Production-Based CO_2 Productivity (GDP per unit of energy-related CO_2 emissions) (CO2GDP); CO_2 Intensity Based on Production (CO_2 related to energy per capita) (ICO2P); CO_2 GDP intensity (CO_2 emissions per unit of GDP) (ICO2GDP); Energy Productivity (GDP per unit of total primary energy supply) (EnProd); Renewable	OCDE	-

		Energy Supply (excluding solid biofuels) in Relation to Total Energy Supply (RES-TES); Productivity of Non-Energy Materials (GDP per unit of domestic material consumption) (PNEM)		
Moderating Varibles	SIZE	**Factor Analysis of the variables:** Total revenue; Total Assets	Thomson Reuters	Ruigrok & Wagner (2003); Capar & Kotabe (2003); Chiarvesio et al. (2015).
	PERF	**Factor Analysis of the variables:** ROA; ROE	Thomson Reuters	Borsatto et al., (2020).

Based on the definition of the study hypotheses, the model's variables and the identification of the constructs to measure Green Innovation, Green Technology and Green Growth, a conceptual model was proposed to identify the relationship between the variables, depicted in Figure 1.

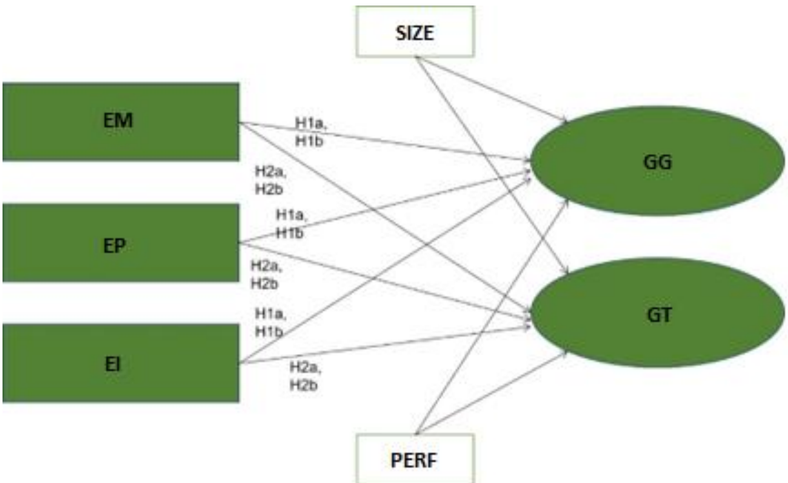

Figure 1 - Conceptual Framework

3.3 Model of Structural Equations

The data analysis was conducted using the Structural Equation Modeling technique, which, according to Hair et al. (2005), allows for a simultaneous analysis of relationships among multiple variables. It facilitates testing of complex conceptual structures for robust data analysis.

4. Results and Discussion

4.1 Measurement Model

Confirmatory Factor Analysis (CFA) assessed construct validity in the measurement model. Factor loadings of the measurement model were calculated, the reliability of each item was examined using composite reliability (CR), convergent validity was assessed using the average variance extracted (AVE), and discriminant validity of the measures associated with each construct was evaluated based on the square root of the AVE value on the diagonal and the correlation among the respective constructs.

Table 2 presents the composite reliability (CR), average variance extracted (AVE), of the constructs, and the discriminant validity of the measurement model for the group of developed countries (DC). It can be observed that both in terms of composite reliability (CR) and average variance extracted (AVE), the values of all constructs are above 0.7 (CR) and 0.5 (AVE) – values recommended in the literature, so all constructs in the model demonstrate sufficient convergent validity. Discriminant validity is achieved as the numbers on the diagonal are higher than the values in their respective rows and columns. In addition, the VIF (Variance Inflation Factor) found was below 5, indicating the absence of multicollinearity issues. The results are presented in Appendix I.

Table 2 - Evaluation of Convergent Validity, Composite Reliability, and Discriminant Validity – DC

	PERF	EM	EI	EP	SIZE	GT	GG
PERF	**1.000**						
EM	0.082	**0.767**					
EI	0.029	0.591	**0.763**				
EP	0.100	0.702	0.558	**0.765**			
SIZE	0.020	0.227	0.266	0.163	**0.990**		
GT	0.026	0.315	0.222	0.301	**0.059**	**0.835**	
GG	-0.044	-0.401	-0.245	-0.360	**-0.128**	**-0.529**	**0.973**
CR		0.842	0.789	0.889	0.982	0.939	0.985
AVE		0.589	0.583	0.585	0.979	0.697	0.947

Table 3 - Convergent Validity, Composite Reliability and Discriminant Validity - EC

	GG	PERF	EM	EI	EP	SIZE	GT
GG	**1.000**						
PERM	0.065	**1.000**					
EM	0.202	-0.020	**0.666**				
EI	0.269	-0.017	0.434	**0.718**			
EP	0.269	-0.043	0.600	0.450	**0.713**		
SIZE	0.340	0.070	0.179	0.341	**0.169**	**0.966**	

GT	-0.488	-0.090	0.025	-0.233	**0.000**	**-0.366**	**0.889**
CR			0.757	0.808	0.858	0.966	0.883
AVE			0.544	0.516	0.508	0.933	0.791

In Table 3, representing the group of least emerging countries (EC), it was found that both in terms of composite reliability (CR) and average variance extracted (AVE), the values of all constructs are above 0.7 (CR) and 0.5 (AVE), indicating that all constructs in the model demonstrate a sufficient level of convergent validity. Moreover, discriminant validity is achieved as the numbers on the diagonal are higher than the values in their respective rows and columns. The VIF (Variance Inflation Factor) found was below 5, indicating the absence of multicollinearity issues. The results are presented in Appendix I.

4.2 Structural Model Analysis

Table 4 presents the results of the Structural Model generated by Structural Equation Modeling. In the developed countries (DC), the company's GI practices positively affect the Green Technology of the countries (EM -> GT coef. 0.355 p=0.000; EI -> GT coef. 0.105 p=0.003; EP -> GT coef. 0.208 p=0.000). However, this does not reflect on Green Growth, as Environmental Management and Environmental Policies negatively impacted it (EM -> GG coef. -0.542 p=0.000; EP -> GG coef. -0.164 p=0.000). On the other hand, the Environmental Investments practice was not statistically significant as it had p=0.573. Therefore, Hypothesis H_{2a} is accepted, and Hypothesis H_{1a} is rejected. The size (SIZE) of the companies negatively moderates the relationship between EM -> GT and EP -> GT, while Environmental Investments, despite size having a positive moderating effect, did not reach statistical significance. Regarding GG, the size of companies has a positive and statistically significant moderating effect on the relationship between EM and EP with the country's GG. However, in the relationship between EI and GG, the size of the companies has a negative effect. The companies' performance (PERF), measured by ROE, does not have a statistically significant moderating effect on any relationship between the company's GI practices and the country's GT and GG.

Table 4 - Structural Model Results

	COEF.		**MEAN**		**DP**		**T-Value**		**P values**	
	DC	**EC**	**DC**	**EC**	**DC**	**EC**	**DC**	**EC**	**DC**	**EC**
PERF -> GT	0.068	0.040	0.066	0.052	0.022	0.038	3.040	1.054	0.002	0.292
PERF -> GG	-0.016	-0.009	-0.018	-0.024	0.014	0.046	1.145	0.204	0.252	0.839
EM -> GT	0.355	0.075	0.356	0.084	0.039	0.072	9.073	1.050	0.000	0.294
EM -> GG	-0.542	0.236	-0.541	0.229	0.040	0.071	13.660	3.318	0.000	0.001
EI -> GT	0.105	0.204	0.107	0.205	0.036	0.062	2.968	3.272	0.003	0.001
EI -> GG	0.020	-0.458	0.021	-0.459	0.036	0.062	0.563	7.449	0.573	0.000
EP -> GT	0.208	-0.076	0.205	-0.076	0.040	0.121	5.143	0.629	0.000	0.529
EP -> GG	-0.164	0.639	-0.161	0.645	0.039	0.131	4.258	4.891	0.000	0.000

SIZE -> GT	0.785	2.743	0.800	2.707	0.102	0.433	7.686	6.332	0.000	0.000
SIZE -> GG	-1.161	-2.835	-1.183	-2.829	0.142	0.512	8.164	5.532	0.000	0.000
SIZE x EM -> GT	-0.352	0.121	-0.350	0.128	0.085	0.145	4.128	0.834	0.000	0.404
SIZE x EM -> GG	0.631	0.091	0.631	0.077	0.107	0.146	5.883	0.620	0.000	0.535
SIZE x EP -> GT	-0.317	-2.055	-0.332	-2.031	0.114	0.372	2.779	5.521	0.005	0.000
SIZE x EP -> GG	0.318	1.786	0.337	1.787	0.126	0.432	2.530	4.135	0.011	0.000
SIZE x EI -> GT	0.026	0.060	0.026	0.053	0.030	0.067	0.866	0.889	0.387	0.374
SIZE x EI -> GG	-0.058	0.068	-0.059	0.077	0.026	0.074	2.273	0.912	0.023	0.362
PERF x EM -> GT	-0.151	-0.170	-0.145	-0.165	0.093	0.094	1.619	1.810	0.105	0.070
PERF x EM -> GG	0.126	0.089	0.130	0.088	0.089	0.100	1.409	0.891	0.159	0.373
PERF x EP -> GT	-0.081	0.011	-0.080	0.003	0.074	0.072	1.099	0.147	0.272	0.883
PERF x EP -> GG	-0.141	-0.043	-0.132	-0.037	0.091	0.077	1.549	0.555	0.121	0.579
PERF x EI -> GT	-0.035	0.317	-0.044	0.321	0.036	0.092	0.973	3.457	0.331	0.001
PERF x EI -> GG	0.086	-0.228	0.058	-0.237	0.074	0.103	1.157	2.206	0.247	0.027

In the least developed countries (LDC), the Environmental Management and Environmental Policies Green Innovation practices of the companies were not statistically significant when related to Green Technology (EM -> GT coef. 0.075 p=0.294; EP -> GT coef. -0.076 p=0.529). On the other hand, Environmental Investments had a positive impact on the country's Green Technology (EI -> GT coef. 0.204 p=0.001). Regarding the promotion of Green Growth, Environmental Management and Environmental Policies had a positive impact (EM -> GG coef. 0.236 p=0.001; EP -> GG coef. 0.639 p=0.000). However, the Environmental Investments practice had a negative impact on Green Growth (EI -> GG coef. -0.458 p=0.000). Therefore, Hypotheses H_{2b} and H_{1b} are accepted. In these countries, the size of companies negatively moderates the relationship between EP -> GG and positively moderates the relationship between EP -> GT. On the other hand, PERM negatively moderates the relationships between EM -> GG and EI -> GT, and positively moderates the relationship between EI -> GG.
In the DC, the tested latent variables explain only 10,7% of the variance in GT and 16,6% of GG. In the LDC, the tested latent variables explain only 17,1% of the variance in GT and 17,7% of GG.
The f^2 assesses how useful each construct is for model fitting. Observing Table 5, all constructs do not have values greater than 0.35, representing a small effect on the overall model fitting, as shown in Table 6.

Table 6 - Results of the model fitting

	PERF	**EM**	**EI**	**EP**	**SIZE**	**SIZE x EM**	**SIZE x EP**	**SIZE x EI**	**PERF x EM**	**PERF x EP**	**PERF x EI**
GT	0.002	0.010	0.001	0.004	0.011	0.002	0.001	0.000	0.000	0.000	0.000
GG	0.000	0.026	0.000	0.002	0.026	0.008	0.002	0.000	0.000	0.001	0.001

4.3 Discussion

The objective of this research was to explore the impact of companies' adoption of Green Innovation practices on the advancement of Green Technologies and Green Growth in DC and LDC.This analysis involved the application of Structural Equation Modeling (SEM) to investigate the interrelationships between variables. The data utilized to assess the companies' Green Innovation efforts resulted in the identification of three factors (EM, EI, EP), all 33 variable relationships were examined for each construct, relating them to GT and GG.

It can be noted that in DC, the companies' GI practices positively affected the GT of the countries, but this was not reflected in GG. Thus, this study observed that GI practices contribute to the environmental technological transformation, promoting the development of green technologies, which tend to be disseminated, resulting in improved ecological efficiency of the economy in DC, supporting the findings of authors Hickel & Kallis (2020). However, in EC, this positive and statistically significant relationship did not occur, indicating that the GI efforts of companies in these countries do not reflect in environmental technological development and do not promote improved ecological efficiency.

Regarding GG, in DC, GI practices (EM and EP) had a negative impact on GG, against the studies by Chen et al. (2018) and Hickel & Kallis (2020). This may be attributed to the fact that GG indicators are based on the relationship between CO_2 emissions, renewable energy, and GDP, and the results indicate that these actions are not having practical impacts on GG indicators, which consider economic growth without compromising natural capital. As the production system and energy system still rely on non-renewable energy sources, the actions of companies are still insufficient to promote GG in these countries.

Common themes in studies investigating GG indicate that GT and efforts directed towards it support GG (Chen et al., 2018; Hickel & Kallis, 2020). In LDC, this theory was corroborated as EM and EP practices positively impacted GG, and EI positively impacted GT. In these countries, where industries are not the main sources of CO_2 emissions, but rather deforestation, wildfires, and agricultural production (Our World in Data, 2022), the adoption of GI practices by companies has a positive impact on GG. However, EI, measured by Environmental Restoration Initiatives, biodiversity impact reduction, and spending on environmental investments, which are not efficiently implemented by competent authorities, negatively impact GG in these countries.

5. Conclusions

The objective of this study was to examine whether the adoption of GI practices by private companies promotes the development of GT and GG in DC and LDC. To achieve this objective, structural equation modeling was performed using data from large companies and indicators from their respective countries.

The transition towards a sustainable world demands the adoption of sustainability measurement criteria, serving as benchmarks to evaluate companies' and countries' progress. Consequently, this shift would entail a transformation in the economic model, emphasizing recognition for contributions to the common good instead of solely relying on production and sales of products and services as growth indicators (Guinot et al., 2022). In this context, effective sustainable management necessitates substantial investment in new green practices, with governments and companies collaborating in their development and implementation.

The main results indicated that GI practices (EM and EP) adopted by companies have a negative impact on GG in DC and a positive impact on GG in LDC. On the other hand, EI negatively affects GG only in LDC. Regarding GT, GI practices have a positive impact on GT variables only in DC, demonstrating that environmental technological transformation promotes the development of green technologies, which tends to be disseminated, resulting in improved ecological efficiency. Another finding of the study was that company size has a positive impact on GT in both DC and LDC and a negative impact on GG in these countries. However, the company's performance measured by ROE does not have a statistically significant moderating effect on any relationship between GI practices of companies and GT and GG of the countries.

The results showed divergences in relation to the literature, bringing contributions that shed light on a "counter-discussion" of this theme. Regarding GT, the results of the study in the DC corroborated with the studies by Hickel & Kalles (2020), diverging from the results presented in the CE companies. Regarding the GG, the results of the positive impact of GI practices on the GG of the EC corroborated the literature in the studies by Chen et al (2018) and Hickel & Kalles (2020), different from the results presented in the DC.

The results presented divergences in relation to the literature in the field, providing contributions that shed light on a "counter-discussion" of this topic. This study highlights the importance of further research as it reveals unidentified factors that influence the connection between GI and GG, especially in DC, requiring further research on the subject considering other variables. Thus, this work contributes to the literature by showing the need for future studies, since there are unexplained factors that interfere in the relationship between the GI and the GG, especially the DC, demanding further studies on the subject considering other variables. Moreover, this comparative empirical study, which involves companies from both developed and less developed countries across various sectors, aims to enhance our understanding of the linkages between Green Innovation, Green Technology development, and Green Growth in diverse country settings. By addressing this aspect, the research addresses a crucial gap in the existing literature, thereby contributing to the advancement of knowledge in this field.

It is added, as a limitation to this study, the fact that the companies that declared that they invest in Green Innovation may be practicing Green Washing, and also, it is important to emphasize that the period of time for the evaluation if there was an improvement in the performance of the companies green innovation adopters, is short, and these results are expected to be validated in the future.

The contradictions in the research findings can contribute to future investigations that seek to identify the factors that interfere in the relationship between companies' GI and the GT and GG of countries, considering the fundamental role of the private sector in promoting sustainable development. Furthermore, these results demonstrate possible paths for companies and governments to establish goals that contribute to achieving SDG 8 to promote sustainable and inclusive economic growth, SDG 9 to promote inclusive and sustainable industrialization and foster innovation, and SDG 10 to strengthen and revitalize the global partnership for sustainable development.

Acknowledgments*:*
This work was carried out with the support of Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES).

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Appendix I

VIF Results – Developed Countries (DC)	VIF
Biodiversity_Impact_Reduction	1.469
CO2 intensity of GDP, CO2 emissions per unit of GDP	5.070
Environment_Management_Team	1.793
Environment_Management_Training	1.697
Environmental_Expenditures_Investments	2.142
Environmental_Investments_Initiatives	2.028
Environmental_Materials_Sourcing	1.942
Environmental_Restoration_Initiatives	1.374
Environmental_Supply_Chain_Management	2.088
ISO14000_or_EMS	1.461
Percentage of all technologies 1	3.304
Percentage of all technologies 2	2.595
Percentage of collaborations in all technologies	2.148
Policy_Emissions	2.466
Policy_Employee_Health_Safety	1.360
Policy_Energy_Efficiency	2.619
Policy_Environmental_Supply_Chai	1.643
Policy_Water_Efficiency	1.842
Production-based CO2 intensity, energy-related CO2 per capita (Tonnes)	5.070
ROA	1.000
Relative advantage	3.235
Resource_reduction_policy	1.673

VIF Results – Emerging Countries (EC)	VIF
Biodiversity_Impact_Reduction	1.194
Environment_Management_Training	1.148
Environmental_Expenditures_Investments	2.187
Environmental_Investments_Initiatives	2.089
Environmental_Materials_Sourcing	1.655
Environmental_Restoration_Initiatives	1.195
Environmental_Supply_Chain_Management	1.776
ISO14000_or_EMS	1.135
Non-energy material productivity, GDP per unit of DMC (US dollars per kilogram, 2015)	1.000

Percentage of all technologies 2	1.524
Percentage of collaborations in all technologies	1.524
Policy_Emissions	1.542
Policy_Employee_Health_Safety	1.523
Policy_Energy_Efficiency	2.125
Policy_Environmental_Supply_Chai	1.297
Policy_Water_Efficiency	1.635
ROA	1.000
Resource_reduction_policy	1.506