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ESG disclosure and financial performance in two interconnected economic activities affected by the global semiconductor crisis

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Abstract

Research Question: What is the relationship between ESG disclosure and financial performance of two interconnected economic activities in the context of the global semiconductor crisis?

Motivation: The global semiconductor shortage, triggered by the SARS-CoV-2 pandemic, has caused significant disruptions for both automobile and semiconductor manufacturers. This study is unique in its focus on these two interconnected economic activities, automobile and semiconductor manufacturers, which have both felt the effects of the semiconductor shortage crisis triggered by the SARS-CoV-2 pandemic.

Idea: The study conducts a comparative analysis of the relationship between ESG disclosure and financial performance of companies within the two interconnected economic activities in the context of the global semiconductor crisis. This relationship is tested through the lens of two proposed associations: (1) ESG-rated is positively associated with companies' financial performance, and (2) among ESG-rated companies, ESG performance is positively associated with companies' financial performance.

Data and tools: To investigate ESG disclosure in the context of the global semiconductor crisis, the statistical sample consisted of 518 listed companies (75 automobile manufacturers and 443 semiconductor manufacturers) from 2020 to 2022 which totals 1554 panel data observations. SPSS Statistics software was used in the research.

Findings and contribution: The findings suggest that ESG-rated, namely the external evaluation published by the Refinitiv rating agency regarding the disclosure of ESG issues,

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lead to the development of the financial performance of listed companies in the two interconnected economic activities. Furthermore, the results support that for automobile manufacturing companies, the global ESG Score highlighting ESG performance is positively associated with financial performance. From the perspective of the ESG pillars, only Environmental Pillar Score stood out as statistically significant in the automotive industry. Instead, contrary to the theoretical predictions, for semiconductor manufacturing companies, as they are involved in more controversies, the ESG Controversies Score decreases, but the financial performance of these companies increases. For these companies, only Governance Pillar Score stood out as statistically significant and positively associated with financial performance.

Keywords: ESG disclosure, financial performance, global semiconductor crisis, automotive industry, semiconductor industry.

JEL codes: M41, Q56, H12

1. Introduction

Over the past three decades, a variety of frameworks and stages of disclosure have been undergone by corporate sustainability. The focus on sustainability reporting through ESG disclosure is considered beneficial and can improve financial performance and firm value (Constantinescu *et al.,* 2021). According to Huang *et al.* (2023), ESG is a strategic tool that creates value for shareholders and contributes to the sustainable development of companies. The results of the research could be different regarding the ESG performance of the companies, considering the effects of the crisis. Yahya's (2023) research on ESG performance, amidst the SARS-CoV-2 pandemic, revealed that ESG disclosure can decrease profitability and negatively impact the sustainable performance of companies.

The SARS-CoV-2 pandemic and the ensuing global semiconductor crisis have impacted two interconnected industries, namely automobile and semiconductor manufacturers. The semiconductor, essential to modern electronics, this material with properties to conduct electricity, but with an electrical conductivity intermediate between conductors and insulators, is crucial for electronic devices with information manipulation and processing functions (Hossain *et al.*, 2023). With a multitude of systems based on this material called semiconductor, such as electric propulsion system, advanced driver-assistance systems (ADAS), or other automotive systems and equipment (engine management and fuel economy, automotive software and cyber security, safety airbags, anti-lock braking systems (ABS), traction control and stability systems, LED lights, climate control, power seats and windows, heating systems, navigation, touch screens, or phone, internet, Wi-Fi, and Bluetooth connectivity), the automotive industry is increasingly dependent on semiconductor production (Ramani *et al.*, 2022).

Although interconnected, the two economic activities face different environmental issues, specific to the activities carried out. On the one hand, the main environmental issues that interfere with the automotive industry refer to transitioning to electric or hybrid automobiles with low carbon emissions, use renewable energy and resources, recycling automobiles and their electronic components or hazardous materials, as well as using sustainable materials and supporting the circular economy (Ray *et al.*, 2024; Tillu *et al.*, 2024). On the other hand, the semiconductor industry is associated with a very high consumption of ultrapure water and energy, the production of GHG emissions, as well as the production of hazardous chemical waste (Sun *et al.*, 2024; Zhang *et al.*, 2024; Ruberti, 2023; Wang *et al.*, 2023).

Thus, this research analyses the relationship between ESG disclosure and financial performance of companies in the two interconnected economic activities, automobile and semiconductor manufacturing companies, in the context of the global semiconductor crisis triggered by the SARS-CoV-2 pandemic. Two research hypotheses were formulated:
RH_1: *In the two interconnected economic activities, ESG-rated is positively associated with companies' financial performance in a crisis context.*
RH_2: *Among ESG-rated companies, in the two interconnected economic activities, ESG performance is positively associated with companies' financial performance in a crisis context.*

This study is based on a quantitative analysis performed using six independent variables specific to the ESG disclosure and a dependent variable linked to financial performance. The ESG-rated, ESG Score, ESG Controversies Score, Environmental Pillar Score, Social Pillar Score, and Governance Pillar Score are used along with a dependent variable Returns on Gross Profits-to-Assets.

The motivation for conducting this study arises from the need to explore the unexamined effects of the global semiconductor crisis on areas already impacted by the SARS-CoV-2 pandemic, with a particular focus on the relationship between ESG disclosure and the financial performance of companies in the two interconnected economic activities. The contribution of the study consists in (1) addressing the literature gap on ESG disclosure and the global semiconductor crisis, and (2) the novelty of the study reflected in the comparative approach of two interconnected economic activities, automobile and semiconductor manufacturers, affected by the semiconductor shortage crisis triggered by the SARS-CoV-2 pandemic.

This paper is structured in the following sections. The second section of this paper presents a literature review and a development of research hypotheses regarding the relationship between ESG disclosure and financial performance of the two interconnected economic activities in the context of the global semiconductor crisis.

The third section presents the methodology, where sample data, variables used and regression models are presented, and the fourth section contains the results of the analyses and their discussions. In the last part, the conclusions, practical implications, limitations, and future research are presented.

2. Literature review and hypotheses development

In the last three decades, corporate sustainability has gone through a variety of frameworks and stages of disclosure. The World Economic Forum (WEF) held in Davos in 1999 is considered the key moment in supporting a sustainable global economy by all member states and businesses of the United Nations through ESG (Environmental, Social, and Governance) disclosure (Pollman, 2022). ESG is defined as "*the core concept of sustainable development that focuses on the coordination of environmental, social and governance performance rather than financial performance and represents an important indicator of sustainable development"* (Huang *et al.*, 2023. p.1). The ESG concept is often used in other forms and meanings, such as "*ESG disclosure*", "*ESG pillars*", "*ESG-rated"*, "*ESG scores*", or "*ESG performance*" (Gutierrez-Ponce & Wibowo, 2023; Apergis *et al*., 2022; Atif *et al.*, 2022; Aydogmus *et al*., 2022; Eng *et al.*, 2022; Pozzoli *et al.*, 2022; Pulino *et al.*, 2022; Constantinescu *et al.*, 2021; Batae *et al.*, 2020).

Transparency of non-financial information based on internal or external assessments determines a company's ESG disclosure, which is associated with a level of ESG performance. The disclosure of information considers all ESG dimensions that form the ESG pillars, namely environmental, social, and governance (Huang *et al.*, 2023; Atif *et al.*, 2022; Giannopoulos *et al.*, 2022; Pulino *et al.*, 2022; Schiemann & Tietmeyer, 2022; Constantinescu *et al.*, 2021).

Activities related to the Environmental pillar aim to protect and minimize damage to the environment, focusing on issues such as natural resources, pollution, recycling, energy, water, effluents, spill, waste, biodiversity, climate change, greenhouse gas (GHG) emissions, CO_2 emissions, ecological footprint, environmental protection expenditures, and environmental impact. The Social pillar groups together activities that focus on how companies treat their employees, collaborators, and the communities in which they operate. The main issues targeted are employee's relations, working conditions, occupational health and safety, training and employee skills, gender diversity, equal opportunities, non-discrimination and freedom of association, collective bargaining and agreement, child labor, forced and compulsory labor, human and community rights, customer health and safety, labeling and compliance, product responsibility, and social impact. The Governance pillar refers to activities within the company focused on management, the board, and shareholders. The main issues they focus on are board structure, executive, non-executive, and independent board members, audit, compensation, nomination,

policy, and corporate governance committees, cultural, gender, and ethnic minorities diversity in the board, median salary gap, shareholder rights, voting policy, voting right share, and the company's CSR (Corporate Social Responsibility) strategy and its integration into management plans (Lee *et al*., 2023; LSEG Data & Analytics, 2023; Giannopoulos *et al.*, 2022; Pulino *et al.*, 2022; Batae *et al.,* 2020).
ESG-rated refers to the external evaluation carried out and published by the rating agencies based on information collected from different public sources, annual reports, websites, or third-party research (Fikru *et al.*, 2024; Eng *et al.*, 2022). Over time, the presence of many rating agencies in the field of ESG disclosure has been established, including MSCI, Sustainalytics, Bloomberg, Refinitiv, FTSE Russell, S&P, and Moody's. All rating agencies in the field publish ESG scores (Gutierrez-Ponce & Wibowo, 2023; Apergis *et al*., 2022; Constantinescu *et al.*, 2021) related to the rated companies, which measure the level of ESG disclosure, on a scale of 0 to 100. Furthermore, the publication of ESG scores by rating agencies contributes to the consolidation of strategic decisions of shareholders, management, investors, or other stakeholders based on the ESG performance of companies measured through ESG scores (Fikru *et al.*, 2024; Lee *et al*., 2023; Eng *et al.*, 2022; Erhart, 2022). Thus, the external evaluation carried out and published by the rating agencies through ESG scores contributes to the assessment of the transparency of the companies' non-financial information, from insufficient level of transparency in ESG disclosure and poor relative ESG performance to high level of transparency in ESG disclosure and excellent relative ESG performance (Huang *et al.*, 2023; Aydogmus *et al*., 2022; Pozzoli *et al*., 2022; Shakil, 2021).

According to Gillan *et al.* (2021) a company's ESG disclosure is often analysed in relation to various topics, such as market characteristics, boards, executives, and executive compensation, ownership characteristics, firm risk, and firm performance and value. One of the most debated research hypotheses is represented by the relationship between ESG disclosure and firm value (Aydogmus *et al*., 2022; Constantinescu *et al.*, 2021) or financial performance (Chen *et al*., 2023; Aydogmus *et al*., 2022; Giannopoulos *et al.*, 2022; Pulino *et al.*, 2022; Batae *et al.,* 2020). However, financial performance, which remains a fundamental element for shareholders, management, investors, or stakeholders, is still a topic of interest for researchers and businesses in the context of its analysis in relation to ESG disclosure (Gillan *et al.*, 2021; Batae *et al.,* 2020).

On the one hand, from a global perspective of the sample of companies, Aydogmus *et al*. (2022) and Chen *et al*. (2023) highlight the positive relationship between ESG disclosure, measured by ESG scores, both globally and for each pillar, and companies' financial performance, measured by Return on Assets (ROA). On the other hand, based on specific samples of companies, Batae *et al.* (2020) conclude positive correlations between ESG disclosure and financial performance of European banks, while Giannopoulos *et al.* (2022) highlight, in the case of

Norwegian listed companies, the negative relationship between ESG score and the financial performance indicator ROA. Similarly, Pulino *et al.* (2022) concludes, for a sample of Italian listed companies for the period 2011-2020, the positive relationship between ESG disclosure based on scores and companies' financial performance highlighted by the Earnings Before Interests and Taxes (EBIT) indicator, as well as the negative relationship between environmental pillar score and financial performance measured by ROA. In another specific context, where the supply chain seems decisive for the financial performance of automobile manufacturing companies based on the correlation of sales in the automotive industry with the level of production in the semiconductor industry (Frieske & Stieler, 2022), ESG disclosure stands out with different influences.

Through a survey addressed to stakeholders in automobile manufacturing companies, Ray *et al.* (2024) point out that respondents believe that social responsibility practices, the correlation of environmental and social performance with market valuation, and the development of an integrated corporate strategy based on ESG principles have a positive influence on the value of automobile manufacturers. Moreover, Dinca *et al.* (2022) conclude a mixed set of results in the context of analysing the relationship between ESG scores and the value of the world's automobile manufacturing companies, while Chandrasekaran (2022) shows through a random effects regression analysis for the period 2009-2020 that for Asian automobile manufacturers, ESG disclosure based on the ESG score positively influences financial performance as measured by ROA and ROE. At the same time, positive relationships were also found at the level of the environmental and social pillars, but a negative relationship between the governance pillar score and the financial performance measures. Similarly, other authors have focused on semiconductor manufacturers. Dagestani *et al.* (2024) concludes the positive relationship between the pollution information transparency index of the cities of residence of semiconductor companies listed on the Shanghai and Shenzhen Stock Exchanges of China and their financial performance as measured by ROA and ROE indicators. Also, Sun *et al.* (2024) show that the environmental pillar score is in a positive relationship with the efficiency of Chinese listed semiconductor manufacturing companies, and Li *et al.* (2024) discuss the relationship between ESG disclosure and financial performance of Taiwan Semiconductor Manufacturing Company (TSMC), the world's largest semiconductor manufacturer.

The interconnection of the two economic activities, namely automobile and semiconductor manufacturers, is based on the term "*semiconductor*". This refers to a material with properties to conduct electricity, but with an electrical conductivity intermediate between conductors and insulators, making them ineffective in conducting electricity. Among the most remarkable semiconductor materials are silicon (Si), germanium (Ge), gallium arsenide (GaAs), cadmium sulfide (CdS), indium arsenide (InAs), or indium phosphide (InP) as identified by Hossain *et al.*

(2023) and Ruberti (2023). Today, however, semiconductors are essential to modern electronics. Through their ability to control the flow of electrical current, they are crucial for electronic devices with information manipulation and processing functions (Hossain *et al*., 2023). According to Frieske and Stieler (2022), Hossain *et al*. (2023), Ruberti (2023), and Zhang *et al*. (2024), the semiconductor industry stands out as an essential core of the global economy, as economic activities in telecommunications, automotive, healthcare, consumer and industrial electronics, or military equipment depend on its efficiency and effectiveness. Thus, among other things, the automotive industry is increasingly dependent on semiconductor production (Ramani *et al*., 2022). The production of electric or hybrid automobiles equipped with an electric propulsion system, advanced driver-assistance systems (ADAS) (autopilot, automatic braking systems, sensor systems), or other automotive systems and equipment, such as engine management and fuel economy, automotive software and cyber security, safety airbags, anti-lock braking systems (ABS), traction control and stability systems, LED lights, climate control, power seats and windows, heating systems, navigation, touch screens, or phone, internet, Wi-Fi, and Bluetooth connectivity, all rely on semiconductors (Frieske & Stieler, 2022; Ramani *et al*., 2022; Deloitte, 2019).

Although interconnected, the two economic activities face different environmental issues, specific to the activities carried out. The main environmental issues that interfere with the automotive industry refer to reducing the impact of climate change by transitioning to electric or hybrid automobiles with low carbon emissions, reducing energy and water consumption by adopting measures to use renewable energy and resources, recycling automobiles and their electronic components or hazardous materials, as well as using sustainable materials and supporting the circular economy (Ray *et al.*, 2024; Tillu *et al.*, 2024). Regarding the semiconductor industry, it is associated with a very high consumption of ultrapure water and energy, the production of GHG emissions, as well as the production of hazardous chemical waste (Sun *et al.*, 2024; Zhang *et al*., 2024; Ruberti, 2023; Wang *et al.*, 2023). Hsieh *et al.* (2023) highlight, in the case of Taiwan Semiconductor Manufacturing Company Limited (TSMC), the world's largest semiconductor manufacturer (Li *et al.*, 2024), hat it used a volume of 77.3 million metric tons of water in 2020, equivalent to the water consumption of about 7.3 million people. According to Wang *et al.* (2023), the water consumption generated by 27 semiconductor manufacturers in 2021 reached the level of a city with a population of 1.88 million inhabitants, and the energy consumption was equivalent to the consumption generated by a city with 25.2 million inhabitants. Instead, the social and governance issues of the two economic activities are considered similar. Both activities are focused on social aspects such as the rights, health and safety of employees and communities. Also, the governance practices applied by the management, board, or shareholders are essential for the integration of environmental and social issues in the business strategies of the two economic activities (Ray *et al.*, 2024; Sun *et al.*, 2024; Tillu *et al.*, 2024; Zhang *et al*., 2024; LSEG Data & Analytics, 2023).

Perello-Marin *et al.* (2022) observed that the automotive industry faced pressures to report non-financial information, but no clear non-financial reporting methodologies had been developed. Similarly, the semiconductor industry is also under pressure to address ESG issues with the same rigor as in financial reporting (EY, 2022).

Since 2020, the world has experienced a significant supply shortage of semiconductors, with the SARS-CoV-2 pandemic being one of the reasons blamed for this crisis (Ochonogor *et al*., 2023; Frieske & Stieler, 2022; Mohammad *et al.*, 2022; Ramani *et al.*, 2022). The temporary closure of semiconductor manufacturers and the increase in demand for electronic equipment, such as laptops, tablets, or mobiles, effects of the SARS-CoV-2 pandemic, have generated an increase in demand for the semiconductors needed to manufacture electronic equipment. Thus, the semiconductor crisis took shape due to the increase in the level of demand over the production capacity in the context of the SARS-CoV-2 pandemic (Ochonogor *et al*., 2023; Frieske & Stieler, 2022). Furthermore, other events in the semiconductor industry, such as fires in Japanese semiconductor factories that halted production or the cold snap in Austin, Texas, North America (USA) that limited production for 1-1.5 months, have contributed to the semiconductor crisis (Frieske & Stieler, 2022; Ramani *et al.*, 2022). According to Frieske and Stieler (2022), the events associated with the semiconductor crisis affected, among others, the manufacturers Asahi Kasei Microsystem (AKM) and NXP Semiconductors N.V., important suppliers of semiconductors for the automotive industry.

In this context of crisis, the relationship between the automotive and semiconductor industries has changed. At the start of the pandemic, falling sales led to a reduction in automobiles production and the cancellation of many semiconductor orders. Instead, as customer interest grew, the supply chain of semiconductors needed for automobile production was blocked due to the semiconductor crisis (Frieske & Stieler, 2022; Mohammad *et al.*, 2022; Ramani *et al.*, 2022). On the one hand, preventive measures against the effects of the semiconductor crisis have been adopted by some automobile manufacturers, such as BMW and Stellantis, which have entered into agreements with semiconductor manufacturers to reserve their future supplies (Ramani *et al.*, 2022). On the other hand, due to the lack of semiconductors in the supply chain, automobile manufacturers adopted measures such as reducing working hours (Audi, Daimler, Volkswagen) or temporarily closing some factories (BMW, Daimler, Ford) (Frieske & Stieler, 2022; Ramani *et al.*, 2022).

In the light of the above, and within the context of the global semiconductor crisis impacting the two interconnected economic activities, this paper endeavours to expand knowledge on the relationship between ESG disclosure and financial performance, focusing on ESG-rated provided by rating agencies and the scores they publish which determine ESG performance. In addition to internal ESG evaluations, rating agencies compile a variety of ESG-related information from multiple sources

and provide stakeholders with an external evaluation of ESG disclosure (Fikru *et al.*, 2024; Eng *et al.*, 2022). Consistent with this perspective, the first research hypothesis is formulated as follows:
RH_1: *In the two interconnected economic activities, ESG-rated is positively associated with companies' financial performance in a crisis context.*

In addition, as presented above, each ESG-rated company is assigned an ESG score that measures the level of ESG performance, on a scale of 0 to 100 (Fikru *et al.*, 2024; Lee *et al*., 2023; Eng *et al.*, 2022; Erhart, 2022). In general, companies with high ESG performance were associated with significantly higher revenue, profitability, and firm valuation during the SARS-CoV-2 pandemic (Yahya, 2023). Similar to Chandrasekaran (2022), Sun *et al.* (2024), and Li *et al.* (2024), the research of the association between ESG performance and financial performance of the two interconnected economic activities stands out as being of interest to businesses and researchers. Thus, the second research hypothesis is formulated as follows:
RH_2: *Among ESG-rated companies in the two interconnected economic activities, ESG performance is positively associated with companies' financial performance in a crisis context.*

According to LSEG Data & Analytics (2023), the Refinitiv rating agency publishes for each company it rates an ESG Combined Score that highlights the company's overall ESG performance. This score is determined based on performance related to ESG issues commonly associated with the company (ESG Score) and which is discounted by significant ESG controversies affecting the company (ESG Controversies Score). As expected, the ESG Score registers different mean values by sample, period, or industry. Mean ESG Scores between 56 - 60 points are highlighted in the case of global automobile manufacturers (Dinca *et al.*, 2022), while Chandrasekaran (2022) concludes a mean score of around 46 points in the case of Asian automobile manufacturers. The world's largest semiconductor manufacturer also recorded an ESG Score of around 68 points over the period 2012-2022 (Li *et al.*, 2024). Therefore, the following research sub-hypothesis is formulated:
$RH_{2.a.}$: *ESG Score is positively associated with companies' financial performance.*

Gaining the interest and confidence of investors is important in times of crisis. Any information, such as media information that can affect a company's reputation, could affect its value and financial performance. If a company's image is associated with historical or ongoing sustainability-linked scandals, such as monopolistic practices, corruption, negative workplace events, or environmental incidents, a reluctance on the part of investors and consumers in relations with that company is expected (Passas *et al.*, 2022). Also, LSEG Data & Analytics (2023) explains that the ESG Controversies Score is calculated considering negative ESG events in which the company is involved. The Volkswagen automobile manufacturer has faced a decrease in company value of around 20% within days and total costs of 6.7 billion euros due to the Volkswagen emissions scandal. This controversy revealed that the company had installed illegal software in about 11 million diesel vehicles to

manipulate nitrogen oxide emissions during laboratory emissions testing. When not tested, emissions were up to 40 times higher (Xue *et al.*, 2023). The second research sub-hypothesis is formulated as follows:
RH$_{2.b.}$: *ESG Controversies Score is positively associated with companies' financial performance.*

Finally, according to LSEG Data & Analytics (2023), the ESG Score consists of all its pillars, namely environmental, social, and governance, with each company being associated with an independent score for each pillar. The scores for the ESG pillars are found in the descriptive analyses with values of 6 - 9 points for Italian listed companies (Pulino *et al.*, 2022), 16 - 25 points for listed companies in the energy industry (Constantinescu *et al.*, 2021), or 38 - 60 points for automobile manufacturers (Chandrasekaran, 2022; Dinca *et al.*, 2022). Therefore, three other research sub-hypotheses are formulated as follows:
RH$_{2.c.}$: *Environmental Pillar Score is positively associated with companies' financial performance.*
RH$_{2.d.}$: *Social Pillar Score is positively associated with companies' financial performance.*
RH$_{2.e.}$: *Governance Pillar Score is positively associated with companies' financial performance.*

3. Data and Methodology

From a methodological point of view, the relationship between ESG disclosure and the financial performance of companies in the two interconnected economic activities, namely automobile and semiconductor manufacturers, in the context of the global semiconductor crisis was based on quantitative research. Most of the time, sustainable development was treated from a quantitative perspective in relation to firm value or financial performance on different statistical samples: (1) listed companies (Cao *et al.*, 2023; Aydogmus *et al.*, 2022; Giannopoulos *et al.*, 2022; Noordewier & Lucas, 2020), (2) a field of activity or groups of industries (Dagestani *et al.*, 2024; Caby *et al.*, 2022; Dinca *et al.*, 2022; Batae *et al.,* 2020; Noordeweir & Lucas, 2020), or (3) depending on the level of development of the countries (Maury, 2022; Batae *et al.,* 2020). The contribution of this study is reflected in the comparative approach of the two interconnected economic activities by referring to an uncertain period determined by a socioeconomic event, the global semiconductor crisis triggered by the SARS-CoV-2 pandemic.
In this section, the data of the statistical sample, the description of the variables included in the analysis, followed by the regression models related to the proposed research hypotheses are presented.

3.1 Sample data

The statistical sample extracted for the analysis of the relationship between ESG disclosure and financial performance was based on all listed companies from the two interconnected economic activities included by the Refinitiv rating agency in its

Eikon database, respectively 75 automobile manufacturers and 443 semiconductor manufacturers, resulting in a sample of 518 listed companies. The Refinitiv Eikon database was used for this quantitative research, which has also been used by other researchers in the analysis of ESG disclosure (Gutierrez-Ponce & Wibowo, 2023; Aydogmus *et al.*, 2022; Chandrasekaran, 2022; Erhart, 2022; Gigante & Manglaviti, 2022; Pozzoli *et al.*, 2022; Constantinescu *et al.,* 2021; Batae *et al.,* 2020). The selection of the sample from the Refinitiv Eikon database was made by filtering companies according to The Refinitiv Business Classification (TRBC), applying the criterion: TRBC Activity Name = Auto & Truck Manufacturers (NEC) or Semiconductors (NEC).

In line with the research hypotheses, a statistical sample was developed for each. On the one hand, the analysis of the association between ESG-rated (1 if the company's ESG disclosure has been externally evaluated and published by the Refinitiv rating agency, and 0 otherwise) and financial performance (**RH_1**) was based on all listed companies from the two interconnected economic activities, 518 listed companies from 2020 to 2022 which totals 1554 panel data observations (Table 1, Panel A). On the other hand, focusing on ESG-rated companies, the sample for the analysis of the association between ESG performance and financial performance (**RH_2**) in the two interconnected economic activities consisted of 156 listed companies from 2020 to 2022 which totals 414 panel data observations (Table 1, Panel B).

To avoid distortion of the regression results, missing data of the dependent and control variables and outliers of the dependent variable were data trimmed from the database. To identify outliers of the dependent variable, the InterQuartile Range (IQR) method was used. The principle of the IQR method is that values outside the range from (25th Percentile - 1.5 x IQR) to (75th Percentile + 1.5 x IQR) are considered outliers, where IQR is defined as the difference between the 75th Percentile and the 25th Percentile (Dash *et al.*, 2023).

Thus, in the context of the global semiconductor crisis, the final sample for the two interconnected economic activities consisted of 174 (for automobiles) and 1173 (for semiconductors) panel data observations that were included in the analysis of the association between ESG-rated and financial performance (**RH_1**), respectively 94 (for automobiles) and 300 (for semiconductors) panel data observations that were included in the analysis of the association between ESG performance and financial performance of companies for which ESG disclosure has been externally evaluated and published by the Refinitiv rating agency (**RH_2**).

Table 1. Sample Data

Panel	Overall	Automobile Manufacturers	Semiconductor Manufacturers
Panel A: ESG-rated and financial performance			
Number of listed Companies	518	75	443
Initial Observations for the period 2020 - 2022	1554	225	1329

Panel	Overall	Automobile Manufacturers	Semiconductor Manufacturers
Panel A: ESG-rated and financial performance			
Less: Observations dropped due to insufficient data to Returns on Gross Profits-to-Assets (the dependent variable)	(74)	(30)	(44)
Less: Observations dropped due to insufficient data to control	(60)	(11)	(49)
Less: Observations dropped due to data trimming of outliers	(73)	(10)	(63)
Final Observations for the period 2020 - 2022	1347	174	1173
Number of Final Observations by Region			
Africa	6	6	0
Americas	173	17	156
Asia	1044	125	919
Europe	115	26	89
Oceania	9	0	9
Panel B: ESG performance and financial performance			
Number of Companies listed and reporting ESG factors	156	37	119
Initial Observations for the period 2020 - 2022	414	100	314
Less: Observations dropped due to insufficient data to control	(3)	(2)	(1)
Less: Observations dropped due to data trimming of outliers	(17)	(4)	(13)
Final Observations for the period 2020 - 2022	394	94	300
Number of Final Observations by Region			
Africa	2	2	0
Americas	111	9	102
Asia	220	65	155
Europe	58	18	40
Oceania	3	0	3

Considering the sample of listed companies with more than 50% Asian automobile and semiconductor manufacturers, as well as socioeconomic events, justified the use of the period 2020-2022 to research the relationship between ESG disclosure and financial performance in the context of the global semiconductor crisis. The outbreak of the SARS-CoV-2 pandemic in Wuhan, China, in 2019 estimated to continue until 2023, or even 2024 (Ramani *et al.*, 2022), was considered the most important event associated with the onset of the semiconductor crisis. Also, the fires in Japanese semiconductor factories in October 2020 and March 2021 or the cold snap in Austin, Texas, North America (USA) in February 2021, all contributed to the semiconductor crisis (Frieske & Stieler, 2022; Ramani *et al.*, 2022).

3.2 Variables

The construction of the regression models for the analysis of the relationship between ESG disclosure and the financial performance of companies in the two interconnected economic activities (automobile and semiconductor manufacturers) in the context of the global semiconductor crisis triggered by the SARS-CoV-2 pandemic was based on a dependent variable to quantify financial performance, as well as six independent variables specific to ESG disclosure.

Often, research on business sustainability considers the use of Tobin's Q indicator as a dependent variable (Cao *et al.*, 2023; Aydogmus *et al.*, 2022; Giannopoulos *et al.*, 2022; Constantinescu *et al*., 2021). Similarly, other authors quantified the dependent variables in the form of rates of return to measure the financial performance of companies: Return on assets - ROA (Dagestani *et al.*, 2024; Cao *et al.*, 2023; Aydogmus *et al.*, 2022; Caby *et al.*, 2022; Chandrasekaran, 2022; Maury, 2022; Pulino *et al.*, 2022; Noordewier & Lucas, 2020) or Return on Equity - ROE (Caby *et al.*, 2022; Chandrasekaran, 2022; Maury, 2022). Tobin's Q indicator considers the market value of a company relative to its book value (Cao *et al.*, 2023), while the traditional rates of return are calculated according to the net profit (ROA being the net profit divided by the total assets and ROE the net profit divided by the total equity). For these reasons, in order to reduce the influence of the performance generated by the market and the differences between the tax systems of the countries or the specific tax implications of the two interconnected economic activities, the dependent variable Returns on Gross Profits-to-Assets (gross profit divided by total assets) was selected, also used by Novy-Marx (2013), Acar *et al.* (2018), Kenchington *et al.* (2019).

Novy-Marx (2013) shows the usefulness of the Returns on Gross Profits-to-Assets indicator which is complementary to the book-to-market ratio, but more useful and effective for its use in economic analyses, highlighting the efficiency of using the company's assets to generate gross profit. The global semiconductor crisis triggered by the SARS-CoV-2 pandemic and felt in the period 2020-2022 in the two interconnected economic activities led to influences on the stock exchanges and tax policies adopted by governments (Ochonogor *et al*., 2023; Frieske & Stieler, 2022; Mohammad *et al.*, 2022; Ramani *et al.*, 2022). Thus, the use of a financial performance variable based on gross profit had the role of reducing the influence of the performance generated by the market and the tax differences of the two interconnected economic activities. Moreover, to highlight the high level of industrialization in the two industries, total assets were targeted as an element of activity in the calculation of the dependent variable. Therefore, the use of a Returns on Gross Profits-to-Assets proved to be an optimal dependent variable for measuring financial performance (Kenchington *et al.*, 2019; Acar *et al.*, 2018; Novy-Marx, 2013), which ensured the comparability of the two interconnected economic activities in the context of the global semiconductor crisis.

Figure 1 and Figure 2 show the distribution of the dependent variable Returns on Gross Profits-to-Assets after data is trimmed from outliers using the IQR method.

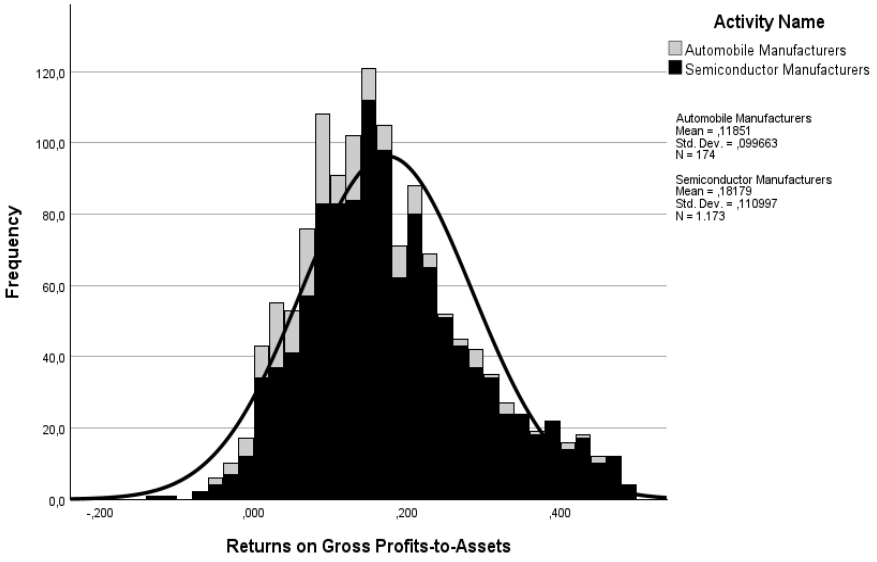

Figure 1. Distribution of the dependent variable: RH_1
Source: the authors' own processing

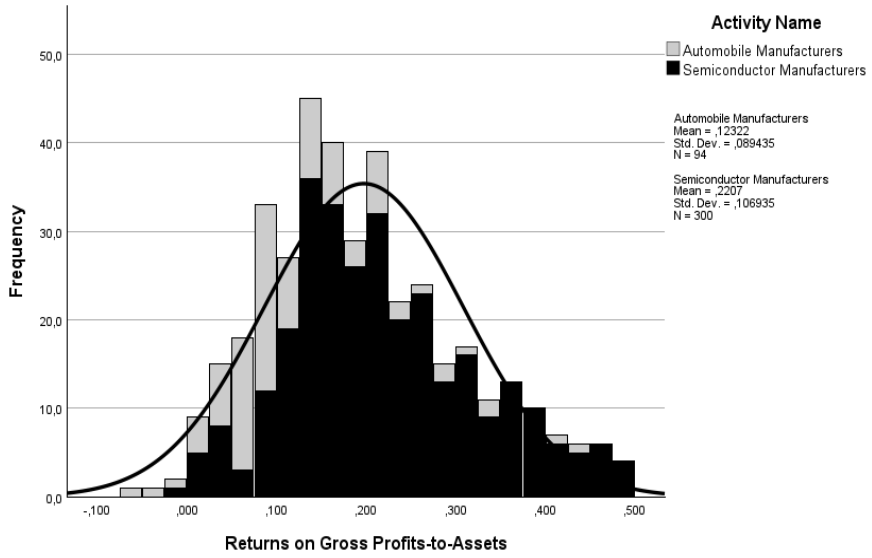

Figure 2. Distribution of the dependent variable: RH_2
Source: the authors' own processing

Six independent variables specific to ESG disclosure of companies were used: ESG-rated, ESG Score, ESG Controversies Score, Environmental Pillar Score, Social Pillar Score, and Governance Pillar Score. On the one hand, previous research considers dummy variables on companies' ESG disclosure (Fikru *et al.*, 2024; Ma & Yoo, 2022; Wieczorek-Kosmala *et al.*, 2021). From this perspective, a dummy variable was used to analyse the association between ESG-rated (1 if the company's ESG disclosure has been externally evaluated and published by the Refinitiv rating agency, and 0 otherwise) and financial performance (**RH_1**) of listed companies from the two interconnected economic activities.

On the other hand, previous research analyses ESG scores from a global perspective (Li *et al.*, 2024; Chandrasekaran, 2022; Dinca *et al.*, 2022; Giannopoulos *et al.*, 2022; Gigante & Manglaviti, 2022), as well as through a detailed approach to ESG pillars: environmental, social, and governance (Li *et al.*, 2024; Sun *et al.*, 2024; Gutierrez-Ponce & Wibowo, 2023; Apergis *et al*., 2022; Chandrasekaran, 2022; Dinca *et al.*, 2022; Batae *et al.*, 2020). The analysis of the association between ESG performance and financial performance (**RH_2**) of the listed companies from the two interconnected economic activities was based on ESG scores.

The ESG Score variable shows, on a scale of 0 to 100, a company's level of transparency in information disclosure and ESG performance on ten main themes (resource use, emissions, innovation, workforce, human rights, community, product responsibility, management, shareholders, and CSR strategy). The ESG Score is made up of the scores for each pillar, namely the Environmental Pillar Score, the Social Pillar Score, and the Governance Pillar Score (Fikru *et al.*, 2024; Lee et al., 2023; LSEG Data & Analytics, 2023). To assess transparency in ESG disclosure and ESG performance of companies using ESG scores, globally or on each pillar, LSEG Data & Analytics (2023) suggests the following reference groups:

- Score from 0 to 25: insufficient level of transparency in ESG disclosure and poor relative ESG performance,
- Score from 25 to 50: moderate level of transparency in ESG disclosure and satisfactory relative ESG performance,
- Score from 50 to 75: above average level of transparency in ESG disclosure and good relative ESG performance,
- Score from 75 to 10: high level of transparency in ESG disclosure and excellent relative ESG performance.

Also, according to LSEG Data & Analytics (2023) and Passas *et al.* (2022), the ESG Controversies Score variable shows, on a scale of 0 to 100, a company's ESG performance in relation to its level of involvement in negative ESG events and controversies. A score of 100 indicates excellent relative ESG performance and no ESG controversy, while a lower score indicates increasing controversy and declining ESG performance.

The measurement of ESG performance on account of the ESG scores provided by the Refinitiv rating agency proved to be appropriate for the comparative analysis of the two interconnected activities considering their calculation methodology that integrates and takes into account the materiality of the industries and the sizes of the companies, as well as the use of the information collected from various public sources, annual reports, websites or third-party research, in order to substantiate the scores (Fikru *et al.*, 2024; Lee et al., 2023; LSEG Data & Analytics, 2023).

In addition, to substantiate the regression models, the control variables used were the size, financial leverage, operational efficiency, and cash flow ratio of the companies. Information on the description, sources, and references of the selected variables for the analysis of the relationship between ESG disclosure and financial performance in the two interconnected economic activities is detailed in Table 2.

Table 2. Variable definitions, sources and references

Variable	Definition*	Source	Reference
Dependent variables			
GP_TA: Returns on Gross Profits-to-Assets	Gross profit for the year divided by book total assets.	Refinitiv Eikon	(Kenchington *et al.*, 2019; Acar *et al.*, 2018; Novy-Marx, 2013)
Independent variables			
ESG: ESG-rated	The company's ESG disclosure has been externally evaluated and published by the Refinitiv rating agency (=1) or not (=0). The value 1 is assigned when the ESG-rated by the Refinitiv rating agency is available for at least one ESG pillar, and 0 otherwise.	Refinitiv Eikon	(Fikru *et al.*, 2024; Atif *et al.*, 2022; Ma & Yoo, 2022; Wieczorek-Kosmala *et al.*, 2021)
ESG_SC: ESG Score	The ESG Score is an overall company score based on the self-reported information in the environmental, social, and governance pillars. From 0 (worst) to 100 (best).		(Li *et al.*, 2024; Sun *et al.*, 2024; Gutierrez-Ponce & Wibowo, 2023; Apergis *et al.*, 2022; Atif *et al.*, 2022; Aydogmus *et al.*, 2022; Chandrasekaran, 2022; Dinca *et al.*, 2022; Pulino *et al.*, 2022; Uyar *et al.*, 2022; Constantinescu *et al.*, 2021; Batae *et al.*, 2020)
ENV: Environmental Pillar Score	The Environmental pillar measures a company's impact on living and non-living natural systems, including the air, land and water, as well as complete ecosystems. This score reflects how well a company uses best management practices to avoid environmental risks and capitalize on environmental opportunities to generate long term shareholder value. From 0 (worst) to 100 (best).		

Variable	Definition*	Source	Reference
SOC: Social Pillar Score	The Social pillar measures a company's capacity to generate trust and loyalty with its workforce, customers and society, through its use of best management practices. This score reflects the company's reputation and the health of its license to operate, which are key factors in determining its ability to generate long term shareholder value. From 0 (worst) to 100 (best).		
GOV: Governance Pillar Score	The Governance pillar measures a company's systems and processes, which ensure that its board members and executives act in the best interests of its long term shareholders. This score reflects a company's capacity, through its use of best management practices, to direct and control its rights and responsibilities through the creation of incentives, as well as checks and balances to generate long term shareholder value. From 0 (worst) to 100 (best).		
ESG_CS: ESG Controversies Score	The ESG controversies category score measures a company's exposure to environmental, social and governance controversies and negative events reflected in global media. From 0 (worst) to 100 (best).		(Agnese *et al.*, 2023; Mendiratta *et al.*, 2023; Schiemann & Tietmeyer, 2022; Treepongkaruna *et al.*, 2022; Shakil, 2021; Batae *et al.*, 2020)
Control variables			
Log (TA): Size	Logarithm of total assets.	Refinitiv Eikon	(Dagestani *et al.*, 2024; Gutierrez-Ponce & Wibowo, 2023; Atif *et al.*, 2022; Aydogmus *et al.*, 2022; Pulino *et al.*, 2022; Uyar *et al.*, 2022)
LEV: Financial Leverage	The ratio of total debt to total assets.		
OE: Operational Efficiency	Operating costs divided by total operating income.		(Caby *et al.*, 2022)
CF: Cash Flow	The ratio of total cash flow to total assets.		(Atif *et al.*, 2022; Ma & Yoo, 2022)

**Source*: Refinitiv Eikon database

3.3 Regression models

To define valid and statistically significant econometric models, the linear parametric regression method was used, based on which the connection and intensity between several independent variables likely to influence the dependent variable were analysed. The dependent variable Returns on Gross Profits-to-Assets was identified and included in the analysis, as well as the six independent variables previously presented and the control variables regarding the size, financial leverage, operational efficiency, and cash flow ratio of the companies. Data were extracted for the period 2020 - 2022 to analysis the relationship between ESG disclosure and the financial performance of companies in the two interconnected economic activities (automobile and semiconductor manufacturers) in the context of the global semiconductor crisis triggered by the SARS-CoV-2 pandemic.

A specific model was defined to test the association between ESG-rated and financial performance of companies within the two interconnected economic activities, in a crisis context (**RH_1**), as follows:

$$GP\_TA_{it} = \beta_0 + \beta_1 ESG_{it} + \beta_2 Log(TA)_{it} + \beta_3 LEV_{it} + \beta_4 OE_{it} + \beta_5 CF_{it} + \gamma_{year} + \varepsilon_{it} \quad (Model\ 1)$$

where GP_TA_{it} is the dependent variable Returns on Gross Profits-to-Assets for testing the association between ESG-rated and financial performance of companies in a crisis context, ESG_{it} is the independent dummy variable showing whether the company's ESG disclosure has been externally evaluated and published by the Refinitiv rating agency (=1) or not (=0), while $Log(TA)_{it}$, LEV_{it}, OE_{it}, and CF_{it} represent control variables on companies' size, financial leverage, operational and cash flow efficiency, γ_{year} as a year dummy variable to control for fixed effects, and ε_{it} as an error term for company *i* in period *t*. Econometric analysis is performed using SPSS Statistics software.

Two specific models were defined for the analysis of the association between ESG performance and financial performance of companies within the two interconnected economic activities, in a crisis context (**RH_2**). First, the association between the global ESG scores (ESG_SC and ESG_CS) and the financial performance of automobile and semiconductor manufacturing companies was tested ($RH_{2.a.}$ and $RH_{2.b.}$). Also, secondly, the association between the ESG pillars scores (ENV, SOC, and GOV) and the financial performance of companies in the two interconnected economic activities ($RH_{2.c.}$, $RH_{2.d.}$, and $RH_{2.e.}$) was tested. The equations are as follows:

$$GP\_TA_{it} = \beta_0 + \beta_1 ESG\_SC_{it} + \beta_2 ESG\_CS_{it} + \beta_3 Log(TA)_{it} + \beta_4 LEV_{it} + \beta_5 OE_{it} + \beta_6 CF_{it} + \gamma_{year} + \varepsilon_{it} \quad (Model\ 2)$$

$$GP\_TA_{it} = \beta_0 + \beta_1 ENV_{it} + \beta_2 SOC_{it} + \beta_3 GOV_{it} + \beta_4 Log(TA)_{it} + \beta_5 LEV_{it} + \beta_6 OE_{it} + \beta_7 CF_{it} + \gamma_{year} + \varepsilon_{it} \quad (Model\ 3)$$

In addition, Model 2 and Model 3 were developed by highlighting the interaction between financial performance of companies in the previous year and ESG scores (global and on pillars) in the current year. This analysis aims to observe the association between ESG performance and financial performance in the context of a lagged influence of the previous year's financial performance, as follows:

$$GP\_TA_{it} = \beta_0 + \beta_1 GP\_TA_{it-1} ESG\_SC_{it} + \beta_2 GP\_TA_{it-1} ESG\_CS_{it} + \beta_3 Log(TA)_{it} + \beta_4 LEV_{it} + \beta_5 OE_{it} + \beta_6 CF_{it} + \gamma_{year} + \varepsilon_{it} \quad (Model\ 4)$$

$$GP\_TA_{it} = \beta_0 + \beta_1 GP\_TA_{it-1} ENV_{it} + \beta_2 GP\_TA_{it-1} SOC_{it} + \beta_3 GP\_TA_{it-1} GOV_{it} + \beta_4 Log(TA)_{it} + \beta_5 LEV_{it} + \beta_6 OE_{it} + \beta_7 CF_{it} + \gamma_{year} + \varepsilon_{it} \quad (Model\ 5)$$

4. Results and Exploratory Insights

4.1 Descriptive statistics

Before testing the econometric models to validate or invalidate the research hypotheses, the data is analysed from a descriptive point of view. In Table 3 the descriptive statistics of the endogenous variable, as well as those of the exogenous and control variables, are presented. The overall descriptive statistics of the listed companies were exposed considering the total number of valid observations after removing missing data and outliers.

The results show higher a Returns on Gross Profits-to-Assets (GP_TA) for listed companies for which the ESG disclosure has been externally evaluated and published by the Refinitiv rating agency. The mean performance rate is 17.4% in the case of all listed companies from the two interconnected economic activities, namely automobile and semiconductor manufacturers. Conversely, in the case of listed companies with ESG scores calculated and published by the Refinitiv rating agency, the mean performance rate is 19.7%. About 29% of the sample companies are externally evaluated by the Refinitiv rating agency in relation to ESG disclosure, and the scores calculated and published by it averaged around 50 points. These indicate that companies have an above average level of transparency in ESG disclosure and relatively good ESG performance (Fikru *et al.*, 2024; LSEG Data & Analytics, 2023; Aydogmus *et al.*, 2022). ESG controversies are noted in the case of less than 25% of listed companies in the two economic activities (ESG_CS different from 100).

Table 3. Descriptive statistics overall

	N	Mean	St. Dev	Min	Q_1	Q_2	Q_3	Max	Skewness	Kurtosis
Panel A: ESG-rated and financial performance										
GP_TA	1347	0.174	0.112	-0.128	0.095	0.157	0.237	0.485	0.564	-0.007
ESG	1347	0.290	0.455	0	0	0	1	1	0.909	-1.175
Log(TA)	1347	8.496	0.992	6.059	7.836	8.377	8.096	11.751	0.741	0.619
LEV	1347	0.197	0.190	0.000	0.040	0.160	0.299	1.999	2.305	13.487
OE	1347	0.694	0.223	-0.113	0.577	0.723	0.822	2.576	0.573	9.611
CF	1347	0.051	0.180	-1.501	0.028	0.080	0.135	0.356	-4.047	23.971
Panel B: ESG performance and financial performance										
GP_TA	394	0.197	0.111	-0.055	0.121	0.180	0.264	0.498	0.547	-0.146
ESG_SC	394	50.590	21.823	8.00	31.96	52.68	68.51	94.00	-0.063	-1.003
ESG_CS	394	89.630	25.276	1.00	100.00	100.00	100.00	100.00	-2.353	4.055
ENV	394	47.640	28.464	0.00	23.84	48.38	70.24	97.00	-0.074	-1.133
SOC	394	50.170	26.279	2.00	28.67	53.28	72.90	94.00	-0.124	-1.175
GOV	394	54.550	20.718	5.00	38.14	54.91	71.13	97.00	-0.079	-0.849
Log(TA)	394	9.506	0.933	6.987	8.824	9.410	10.175	11.751	0.209	-0.263
LEV	394	0.196	0.158	0.000	0.052	0.176	0.290	0.605	0.587	-0.530
OE	394	0.640	0.205	-0.113	0.512	0.663	0.801	1.454	-0.701	1.534
CF	394	0.095	0.105	-0.425	0.053	0.099	0.157	0.356	-1.481	5.356

***Note**: N is the total number of valid observations after data is trimmed out of the outliers. Q_1, Q_2, and Q_3 are 25%, 50% (median) and 75% percentiles*

In addition, the results of the descriptive statistics on the control variables indicate that listed companies for which the ESG disclosure has been externally evaluated and published by the Refinitiv rating agency are larger, more operationally and cash flow efficient, and have better financial leverage. Regarding the normality of the distribution of the main variables, stands out that they have a normal distribution, with skewness and kurtosis within the -2 and +2 range (Hair *et al*., 2022), except for the ESG_CS variable which shows a right skewed and a leptokurtic distribution.

Moreover, Table 4 shows an in-depth descriptive analysis regarding the two interconnected economic activities. The results highlight the fact that semiconductor manufacturing companies have a higher Returns on Gross Profits-to-Assets, are more operationally and cash flow efficient, and have better financial leverage compared to automobile manufacturing companies that are merely larger. The results also show that fewer semiconductor manufacturing companies were externally evaluated by the Refinitiv rating agency in relation to ESG disclosure, about 26%, compared to 54% of automobile manufacturing companies. Furthermore, automobile manufacturers had higher mean ESG scores, but also more ESG controversies.

Referring to other research in the field in which the same sustainability indicators were used, the sample is relevant for both economic activities included in the regression analysis. The ESG_CS was found with mean values of approximately 44 points (Shakil, 2021) to 80-95 points (Agnese *et al.*, 2023; Treepongkaruna *et al.*, 2022). At the same time, ESG_SC, ENV, SOC, and GOV variables are found in research with mean values of approximately 30-40 points (Agnese *et al.*, 2023; Aydogmus *et al.*, 2022; Uyar *et al.*, 2022) to 70-80 points (Apergis *et al*., 2022).

Also, found are scores with mean values of approximately 38 - 60 points in the case of automobile manufacturers (Chandrasekaran, 2022; Dinca *et al.*, 2022), or an ESG score of approximately 68 points in the period 2012-2022 in the case of the world's largest semiconductor manufacturer (Li *et al.*, 2024).

The in-depth descriptive analysis is completed by testing the homogeneity of variances by Levene's test, as well as by applying parametric (Independent Samples T) and non-parametric (Mann-Whitney U) tests. Independent Samples T and Mann-Whitney U tests were performed to determine whether there were differences in the distributions of the variables for the automobile and semiconductor manufacturing companies. The results show a statistically significant difference between the means of the variables of the two economic activities (p-value < 0.5). The assumption of homogeneity of variances was violated for some of the variables, as assessed by Levene's test for equality of variances (p-value < 0.5). In this case, the Mann-Whitney U test for assessing the significant differences between the means of the two economic activities is more relevant.

Table 4. Descriptive statistics cluster – Economic Activity

Economic Activity	Automobile Manufacturers		Semiconductor Manufacturers		Homogeneity of variances	Independent Samples T Test	Mann-Whitney U Test
	N	Mean	N	Mean	Levene's Test		
Panel A: ESG-rated and financial performance							
GP_TA	174	0.119	1173	0.182	4.851*	-0.063**	7.723**
ESG	174	0.540	1173	0.260	50.779**	0.284**	-7.666**
Log(TA)	174	9.456	1173	8.354	107.524**	1.102**	-10.325**
LEV	174	0.281	1173	0.184	18.972**	0.096**	-6.030**
OE	174	0.822	1173	0.675	13.944**	0.147**	-9.989**
CF	174	0.025	1173	0.055	4.485*	-0.031*	6.058**
Panel B: ESG performance and financial performance							
GP_TA	94	0.123	300	0.221	6.221*	-0.097**	8.121**
ESG_SC	94	61.240	300	47.250	0.037	13.983**	-5.371**
ESG_CS	94	70.050	300	95.770	220.855**	-25.724**	8.984**
ENV	94	68.000	300	41.260	0.001	26.736**	-7.917**
SOC	94	57.460	300	47.880	1.890	9.581**	-3.185**
GOV	94	58.210	300	53.410	1.156	4.801*	-1.857
Log(TA)	94	10.398	300	9.227	0.206	1.171**	-10.203**
LEV	94	0.314	300	0.159	16.142**	0.155**	-7.523**
OE	94	0.802	300	0.590	9.110**	0.212**	-10.496**
CF	94	0.055	300	0.108	14.814**	-0.053**	7.413**

***Note**: N is the total number of valid observations after data is trimmed out of the outliers.*
***, * indicate statistical significance at levels of 1 and 5%, respectively.*

Table 5 and Table 6 show the Pearson and Spearman correlation matrices for the variables included in the models, a tool for analysing the link between variables also used by other authors (Dagestani *et al.*, 2024; Mendiratta *et al.*, 2023; Aydogmus *et al.*, 2022; Giannopoulos *et al.*, 2022).

Table 5. Correlation matrix: ESG-rated and financial performance

Variables	GP_TA	ESG	Log(TA)	LEV	OE	CF
GP_TA	1	0.136**	-0.075**	-0.262**	-0.584**	0.595**
ESG	0.134**	1	0.626**	0.023	-0.169**	0.165**
Log(TA)	-0.081**	0.649**	1	0.189**	0.058*	0.216**
LEV	-0.255**	-0.003	0.149**	1	0.348**	-0.204**
OE	-0.513**	-0.160**	0.046	0.244**	1	-0.328**
CF	0.364**	0.138**	0.313**	-0.151**	-0.098**	1

Note: *Pearson and (Spearman) correlations are presented below (above) the diagonal of the matrix. **, * indicate statistical significance at levels of 1 and 5%, respectively.*

The correlation matrices show that there was no significant correlation between the dependent variable GP_TA and the other independent variables included in the models (very weak links). Medium, strong and very strong correlations were observed between the ESG_SC variable and ESG pillars scores, as well as between the ESG_CS variable and ESG pillars scores, which is not a concern given the use of different econometric models. Although there are medium and strong correlations between the independent variables included in *Model 3* regarding the ESG pillars scores, this aspect does not provide the research with sufficient evidence to exclude variables from the model, since the correlation analysis of the variables should not be used for the modification of econometric models (Mendiratta *et al.*, 2023).

4.2 Univariate analysis

At this stage, the distribution of the financial performance of listed companies from the two interconnected economic activities was investigated considering their grouping into companies for which the ESG disclosure has been externally evaluated and published by the Refinitiv rating agency (=1) or not (=0). The results are reported in Table 7, on a nonparametric (Mann-Whitney U test) level, as the dataset is not normally distributed (p-value of Levene's test for equality of variances < 0.5).

Table 6. Correlation matrix: ESG performance and financial performance

Variables	GP_TA	ESG_SC	ESG_CS	ENV	SOC	GOV	Log(TA)	LEV	OE	CF
GP_TA	1	-0.072	0.131**	-0.111*	-0.078	0.077	-0.344**	-0.267**	-0.621**	0.492**
ESG_SC	-0.057	1	-0.463**	0.909**	0.924**	0.592**	0.691**	0.447**	0.122*	0.173**
ESG_CS	0.098	-0.430**	1	-0.442**	-0.428**	-0.249**	-0.574**	-0.371**	-0.080	0.066
ENV	-0.100*	0.910**	-0.403**	1	0.767**	0.399**	0.704**	0.439**	0.192**	0.099
SOC	-0.064	0.925**	-0.395**	0.770**	1	0.376**	0.598**	0.395**	0.113*	0.195**
GOV	0.071	0.605**	-0.243**	0.403**	0.380**	1	0.359**	0.273**	-0.050	0.149**
Log(TA)	-0.305**	0.700**	-0.604**	0.698**	0.614**	0.385**	1	0.553**	0.301**	0.006
LEV	-0.261**	0.441**	-0.410**	0.427**	0.392**	0.260**	0.557**	1	0.310**	-0.189**
OE	-0.487**	0.176**	-0.068	0.221**	0.164**	-0.008	0.315**	0.304**	1	-0.307**
CF	0.424**	0.269**	-0.017	0.196**	0.265**	0.216**	0.208**	-0.088	-0.040	1

Note: *Pearson and (Spearman) correlations are presented below (above) the diagonal of the matrix. **, * indicate statistical significance at levels of 1 and 5%, respectively.*

Table 7. Comparison between groups on ESG-rated (ESG = 0 vs. ESG = 1)

Variables	Mean Ranks ESG = 0	Mean Ranks ESG = 1	Mann-Whitney U Test	z-stat
GP_TA	639.91	756.15	220471.000	4.993**
Log(TA)	517.09	1052.18	337402.000	22.984**
LEV	668.30	687.74	193445.500	0.835
OE	716.33	571.98	147721.000	-6.200**
CF	632.61	773.76	227425.000	6.063**

Note: **, * indicate statistical significance at levels of 1 and 5%, respectively.

The results show statistically significant differences between all variables, except from financial leverage (LEV). The mean ranks of the Mann-Whitney U test clearly indicate that the observations rated with ESG = 1 are distinguished by a higher Returns on Gross Profits-to-Assets. At the same time, observations rated with ESG = 1 are distinguished by a higher operational efficiency and cash flow efficiency. We also find at a statistically significant level that observations rated with ESG = 1 are larger, considering the size of their total assets. These observations indicate that listed companies for which the ESG disclosure has been externally evaluated and published by the Refinitiv rating agency are distinguished by better financial performance. Similarly to our study, Wieczorek-Kosmala *et al.* (2021) conclude the positive and statistically significant association between ESG disclosure based on the externally evaluated carried out by the Refinitiv rating agency and the performance of listed companies in the energy sector.

4.3 Regression analysis

The results of the linear parametric regressions of the econometric models are presented in Table 8, Table 9, and Table 10. The validity of the regression models is supported by the F test, which registers a significance threshold lower than 0.01 in the case of all models. Therefore, there is sufficient evidence to state with a 99% probability that the econometric models are statistically valid. The autocorrelation of residuals for regression models is assessed on the Durbin-Watson test. Values around 2 indicate that no significant autocorrelation was detected in the sample. For the diagnosis of multicollinearity, the use of Variance Inflation Factor (VIF) was considered, similarly to Pulino *et al.* (2022) and Wieczorek-Kosmala *et al.* (2021). The results of this study show that there is no severe multicollinearity problem that occurs between the independent variables (VIF below 5).

Table 8 shows the regression results of Model 1 regarding the association between ESG-rated and financial performance of listed companies in the two interconnected economic activities, in a crisis context.

Table 8. Fixed Effects Regressions Results: ESG-rated and financial performance

	Model 1		
	Overall	**Automobile Manufacturers**	**Semiconductor Manufacturers**
ESG	0.054***	0.053**	0.052***
Log(TA)	-0.036***	-0.030***	-0.037***
LEV	-0.028**	-0.034	-0.025*
OE	-0.207***	-0.124***	-0.221***
CF	0.238***	0.231***	0.244***
Year dummy	Yes	Yes	Yes
R	0.648	0.536	0.646
R Square	0.420	0.287	0.418
Adjusted R Square	0.417	0.257	0.414
F test	138.512***	9.555***	119.292***
Durbin-Watson test	1.575	1.992	1.554
VIF	< 5	< 5	< 5
Model	Fixed Effect	Fixed Effect	Fixed Effect
Observations	1347	174	1173

Note: ****, **, * indicate statistical significance at levels of 1, 5, and 10%, respectively.*

Model 1 shows that ESG-rated, namely the company's ESG disclosure externally evaluated and published by the Refinitiv rating agency, is significantly (p-value < 0.01) and positively associated with Returns on Gross Profits-to-Assets (***RH*$_1$** is accepted). These results indicate that external evaluations published by rating agencies regarding the disclosure of ESG issues lead to the development of the financial performance of listed companies (overall and by category of economic activities). Analysing the ESG disclosure through the externally evaluated carried out by the Refinitiv rating agency of European listed companies in the energy sector, Wieczorek-Kosmala *et al.* (2021), similarly to the results of this study, supported the positive association with operational performance.

Table 9 shows the regression results of Model 2 and Model 3 on the association between ESG performance and financial performance of listed companies, overall and individually for the two interconnected economic activities, in the context of the global semiconductor crisis triggered by the SARS-CoV-2 pandemic.

Model 2, overall, shows that ESG_SC is significantly (p-value < 0.01) and positively associated with Returns on Gross Profits-to-Assets, but the ESG_CS is significantly (p-value < 0.01) and negatively associated with Returns on Gross Profits-to-Assets. Given in-depth regressions of the two interconnected economic activities, the results indicate that ESG performance (ESG_SC) is positively associated with the financial performance of automobile manufacturing companies. Chandrasekaran (2022) highlights similar results, a positive association between ESG score and financial

performance measured by ROA and ROE indicators in the case of the analysis of 21 Asian automobile manufacturers for the period 2009-2020. Instead, the ESG_CS is negatively associated with financial performance of semiconductor economic activity, which highlights that as semiconductor manufacturing companies are involved in more controversies, the ESG_CS decreases, but the financial performance of these companies increases. Thus, $RH_{2.a.}$ is accepted for automobile manufacturers and $RH_{2.b.}$ is rejected for semiconductor manufacturers, otherwise statistically insignificant.

Table 9. Fixed Effects Regressions Results: ESG performance and financial performance

	Model 2			Model 3		
	Overall	**Automobile Manufacturers**	**Semiconductor Manufacturers**	**Overall**	**Automobile Manufacturers**	**Semiconductor Manufacturers**
ESG_SC	0.001***	0.003***	0.000			
ESG_CS	-0.001***	0.000	-0.001***			
ENV				0.001***	0.002***	0.000
SOC				0.000	0.000	0.000
GOV				0.000	0.000	0.000*
Log(TA)	-0.061***	-0.079***	-0.053***	-0.053***	-0.076***	-0.047***
LEV	0.035	-0.100*	0.049	0.047	-0.018	0.059
OE	-0.194***	-0.172***	-0.228***	-0.207***	-0.201***	-0.241***
CF	0.507***	0.338***	0.546***	0.500***	0.392***	0.549***
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
R	0.705	0.742	0.659	0.701	0.767	0.651
R Square	0.497	0.551	0.434	0.492	0.520	0.424
Adjusted R Square	0.486	0.551	0.419	0.480	0.545	0.407
F test	47.485***	13.036***	27.909***	41.253***	13.359***	23.756***
Durbin-Watson test	1.961	2.044	1.840	1.956	2.045	1.820
VIF	< 5	< 5	< 5	< 5	< 5	< 5
Model	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect
Observations	394	94	300	394	94	300

Note: ****, **, * indicate statistical significance at levels of 1, 5, and 10%, respectively.*

Furthermore, from the perspective of ESG pillars, Model 3, as an overall, shows that ENV is significantly (p-value < 0.01) and positively associated with Returns on Gross Profits-to-Assets. Furthermore, the results highlight the positive association between environmental characteristics and financial performance of automobile manufacturing companies, as well as the positive association between governance and financial performance of semiconductor manufacturing companies. For these

reasons, $RH_{2.c.}$ is accepted for automobile manufacturers and $RH_{2.e.}$ is accepted for semiconductor manufacturers, otherwise statistically insignificant.

Regarding the control variables, the results show that as companies are larger and more operationally efficient, their Returns on Gross Profits-to-Assets tend to decrease. However, in line with theoretical predictions, there is a positive relationship between cash flow efficiency and Returns on Gross Profits-to-Assets. Similar influences of company size (Aydogmus *et al.*, 2022; Apergis *et al.*, 2022), operational efficiency (Caby *et al.*, 2022), and cash flow efficiency (Atif *et al.*, 2022; Ma & Yoo, 2022) were found.

Finally, similar to Ma and Yoo (2022), table 10 shows the regression results of Model 4 and Model 5 on the association between ESG performance and financial performance in the context of a lagged influence of the previous year's financial performance for automobile and semiconductor manufacturers.

Table 10. Fixed Effects Regressions Results: ESG performance and the lagged influence of financial performance

	Model 4			Model 5		
	Overall	**Automobile Manufacturers**	**Semiconductor Manufacturers**	**Overall**	**Automobile Manufacturers**	**Semiconductor Manufacturers**
GP_TA_{-1} x ESG_SC	0.004***	0.008***	0.003***			
GP_TA_{-1} x ESG_CS	0.003***	0.002***	0.003***			
GP_TA_{-1} x ENV				0.002**	0.007***	0.000
GP_TA_{-1} x SOC				0.001	-0.001	0.002**
GP_TA_{-1} x GOV				0.005***	0.003*	0.006***
Log(TA)	-0.028***	-0.022***	-0.036***	-0.045***	-0.034***	-0.057***
LEV	0.060**	0.026	0.071**	0.046*	0.047	0.077**
OE	-0.116***	-0.052**	-0.148***	-0.103***	-0.069***	-0.130***
CF	0.290***	0.358***	0.349***	0.313***	0.391***	0.378***
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
R	0.834	0.921	0.793	0.822	0.922	0.779
R Square	0.696	0.848	0.628	0.676	0.850	0.607
Adjusted R Square	0.690	0.834	0.618	0.668	0.834	0.595
F test	110.210***	59.391***	61.532***	89.028***	52.782***	49.775***
Durbin-Watson test	2.076	2.023	2.058	2.013	1.991	2.005
VIF	< 5	< 5	< 5	< 5	< 5	< 5
Model	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect
Observations	394	94	300	394	94	300

Note: ****, **, * indicate statistical significance at levels of 1, 5, and 10%, respectively.*

From the perspective of the results of the association between ESG performance and financial performance in the context of a lagged influence of the previous year's financial performance in the two interconnected economic activities, it was appreciated that the financial performance of the companies from the previous year increases the correlation of the association between the ESG scores and the dependent variable Returns on Gross Profits-to-Assets.

Compared to the results presented previously, the ESG_SC is positively associated with the financial performance of both interconnected economic activities, but also according to the theoretical predictions of Treepongkaruna *et al.* (2022), the ESG_CS is positively associated with the financial performance of the two industries. Moreover, in addition to the environmental characteristics that stand out only in automobile manufacturers, a positive association was noted between SOC and the financial performance of semiconductor manufacturers, but also a positive association between GOV and the dependent variable Returns on Gross Profits-to-Assets in the case of both interconnected economic activities.

For these reasons, the results of *Model* 4 and *Model 5* support that $\boldsymbol{RH_{2.a.}}$, $\boldsymbol{RH_{2.b.}}$, and $\boldsymbol{RH_{2.e.}}$ are accepted for both interconnected economic activities, $\boldsymbol{RH_{2.c.}}$ is accepted for automobile manufacturers, and $\boldsymbol{RH_{2.d.}}$ is accepted for semiconductor manufacturers, otherwise statistically insignificant.

4.4 Discussion

The SARS-CoV-2 pandemic provided an example for future challenges and issues arising from both endogenous and exogenous hazards, such as pandemics, severe climatic conditions, wars, or economic collapse. The semiconductor crisis has provided the automotive and semiconductor industries with valuable experience and key strategic insights, particularly on how companies can enhance their resilience and adaptability to major disruptions. In addition, if the challenges and opportunities are properly understood and appropriate action are taken, crises can also serve as factors for the transition to a more sustainable future that better prepares the world for subsequent crises.

This study focused on the analysis of the relationship between ESG disclosure and financial performance of companies from the two interconnected economic activities in the context of the semiconductor crisis. Table 11 shows the summary of the study results for all the econometric models tested.

On the one hand, $\mathbf{RH_1}$ regarding the association between ESG-rated, namely the company's ESG disclosure externally evaluated and published by the Refinitiv rating agency, and financial performance measured by Returns on Gross Profits-to-Assets is accepted, overall and for both economic activities in the context of the global

semiconductor crisis. Thus, the external evaluations published by the Refinitiv rating agency regarding the disclosure of ESG issues lead to the development of the financial performance of listed companies in the two interconnected economic activities. Moreover, based on univariate analysis, listed companies for which the ESG disclosure has been externally evaluated and published by the Refinitiv rating agency are distinguished by better financial performance not only by Returns on Gross Profits-to-Assets, but also by measures of size, operational efficiency, and cash flow efficiency. This finding is consistent with Wieczorek-Kosmala *et al.* (2021), who reports that there is a positive and statistically significant association between ESG disclosure based on the externally evaluated carried out by the Refinitiv rating agency and the performance of European listed companies in the energy sector for the period 2013-2020. In addition, focusing on external evaluations published by the Korea Corporate Governance Service (KCGS) on ESG disclosure for listed companies on the Korea Stock Exchange, Ma and Yoo (2022) conclude the positive relationship between ESG disclosure-earnings interaction and financial performance as measured by the ratio of net income to total assets.

On the other hand, mixed results were concluded for **RH_2** regarding the association between ESG performance and financial performance of companies in the two interconnected economic activities. In the context of the global semiconductor crisis triggered by the SARS-CoV-2 pandemic, it was found that for automobile manufacturing companies, the global ESG Score highlighting ESG performance is positively associated with financial performance. This finding suggests that as companies adopt a higher level of transparency in information disclosure and ESG performance, automobile manufacturers have better financial performance. From the perspective of the ESG pillars, only Environmental Pillar Score stood out as statistically significant in the automotive industry. Thus, the development of management practices to avoid environmental risks and to capitalize on environmental opportunities to generate long-term shareholder value led to increased Returns on Gross Profits-to-Assets for automobile manufacturers. These findings are partially consistent with Dinca *et al.* (2022) who highlights a mixed set of results in the context of analysing the relationship between ESG scores and the value of the world's automobile manufacturing companies, positive and negative influences of the scores, different from year to year in the period 2015-2020. Also, Chandrasekaran (2022) who highlights in the case of Asian automobile manufacturers in the period 2009-2020 a positive association between the ESG score, as well as the scores of the environmental and social pillars, and the financial performance indicators ROA and ROE. In addition, from a global perspective, Apergis *et al.* (2022) concludes the negative impact of ESG scores on bond yield, while Aydogmus *et al.* (2022) and Chen *et al.* (2023) highlight the positive relationship between ESG scores, globally and for each pillar, and companies' financial performance.

Table 11. Study's results summary

Variables	Research hypotheses	Predictions	Regression results			Regression results with lagged influence			Similar results
			Overall	Automobile Manufacturers	Semiconductor Manufacturers	Overall	Automobile Manufacturers	Semiconductor Manufacturers	
ESG	RH_1	+	+	+	+				(Ma & Yoo, 2022; Wieczorek-Kosmala *et al.*, 2021)
ESG_SC	$RH_{2.a}$	+	+	+	NS	+	+	+	(Li *et al.*, 2024; Chandrasekaran, 2022; Dinca *et al.*, 2022)
ESG_CS	$RH_{2.b}$	+	-	NS	-	+	+	+	(Mendiratta *et al.*, 2023; Treepongkaruna *et al.*, 2022)
ENV	$RH_{2.c}$	+	+	+	NS	+	+	NS	(Li *et al.*, 2024; Sun *et al.*, 2024; Chandrasekaran, 2022; Dinca *et al.*, 2022)
SOC	$RH_{2.d}$	+	NS	NS	NS	NS	NS	+	(Li *et al.*, 2024; Sun *et al.*, 2024; Chandrasekaran, 2022; Dinca *et al.*, 2022)
GOV	$RH_{2.e}$	+	NS	NS	+	+	+	+	(Li *et al.*, 2024; Chandrasekaran, 2022; Dinca *et al.*, 2022)

Note: *NS = no statistical significance.*

Contrary to the theoretical predictions, it was observed that for semiconductor manufacturing companies, as they are involved in more controversies, the ESG Controversies Score decreases, but the Returns on Gross Profits-to-Assets of these companies increases. Treepongkaruna *et al.* (2022) highlighted theoretical claims that companies' profitability is significantly higher when they are involved in fewer ESG controversies. Conversely, ESG controversies have been negatively associated with the value of Indian companies (Mendiratta *et al.*, 2023). The finding that semiconductor companies involved in more ESG controversies perform better was considered as justified at a period in which the semiconductor crisis took shape due to the increase in the level of demand over the production capacity in the context of the SARS-CoV-2 pandemic or other events in the semiconductor industry, such as fires and cold snap (Ochonogor *et al.*, 2023; Frieske & Stieler, 2022; Ramani *et al.*, 2022).

Furthermore, the development of the capacity of semiconductor manufacturing companies, through its use of best management practices, to direct and control its rights and responsibilities through the creation of incentives, as well as checks and balances to generate long term shareholder value led to increased Returns on Gross Profits-to-Assets. Aydogmus *et al.* (2022) presents the positive relationship of the governance pillar with the value and performance of companies. However, Apergis *et al.* (2022) argue for the negative relationship between corporate governance and bond yields and Maury (2022) presents in his results the negative influence of the CSR strategy on the return rates specific to measuring the financial performance of companies. Instead, referring to semiconductor companies, Sun *et al.* (2024) highlight the significant association between the environmental pillar and the efficiency of Chinese listed semiconductor manufacturing companies. Also, Li *et al.* (2024) show through their results that there are no statistically significant relationships between ESG disclosure and financial performance of Taiwan Semiconductor Manufacturing Company (TSMC), the world's largest semiconductor manufacturer.

Finally, according to Ma and Yoo (2022), the lagged influence of the previous year's financial performance strengthens the role of ESG disclosure. Thus, in the context of regression with a lagged influence of the previous year's financial performance, the ESG Score and ESG controversies are positively associated with the Returns on Gross Profits-to-Assets of the two interconnected economic activities. At the level of the ESG pillars, positive associations were found for the environmental and governance pillars in the case of automobile manufacturers, respectively for the social and governance pillars in the case of semiconductor manufacturers.

5. Conclusions

This research aims to expand knowledge about the relationship between ESG disclosure and financial performance, with a focus on ESG-rated by the Refinitiv

rating agency and the scores they publish to determine ESG performance, in the context of the global semiconductor crisis for the two interconnected economic activities. Semiconductors, materials with an electrical conductivity intermediate between conductors and insulators, have become essential in the global economy, as economic activities in telecommunications, automotive, healthcare, consumer and industrial electronics, or military equipment depend on them (Zhang *et al.*, 2024; Hossain *et al.*, 2023; Ruberti, 2023; Frieske & Stieler, 2022). Regarding ESG disclosure, although interconnected, the two industries face different environmental challenges specific to their activities. These range from the growing demand for electric or hybrid vehicles (Ray *et al.*, 2024; Tillu *et al.*, 2024) to the high consumption of ultrapure water and energy in the semiconductor industry (Sun *et al.*, 2024; Zhang *et al.*, 2024; Ruberti, 2023; Wang *et al.*, 2023). Instead, the global semiconductor crisis triggered by the SARS-CoV-2 pandemic led to the blocking of the supply chain of these materials in the relationship between the automotive and semiconductor industries (Frieske & Stieler, 2022; Mohammad *et al.*, 2022; Ramani *et al.*, 2022).

First, the results support **RH$_1$** and affirm the positive association between ESG-rated and financial performance. The external evaluation carried out and published by the Refinitiv rating agency based on information collected from different public sources, annual reports, websites, or third-party research (Fikru *et al.*, 2024; Eng *et al.*, 2022) contributes to the consolidation of strategic decisions of shareholders, management, investors, or other stakeholders (Fikru *et al.*, 2024; Lee *et al.*, 2023; Eng *et al.*, 2022; Erhart, 2022). For these reasons, ensuring the transparency of ESG information through ESG-rated and, implicitly, the substantiation of strategic decisions, is associated with an increase in the financial performance of companies in the two interconnected economic activities.

Second, among ESG-rated companies in the two interconnected economic activities, the results partially support the **RH$_2$** and affirm the positive association between ESG performance and financial performance. In the context of the global semiconductor crisis, automobile manufacturing companies have focused their attention on environmental issues in the industry. Referring to the main environmental issues that interfere with the automotive industry, several economic implications have been deduced. The positive association between ESG performance, as measured by the Environmental Pillar Score, and financial performance in the context of the global semiconductor crisis was primarily attributed to the adoption of environmental practices. Among the most important practices were observed reducing costs by adopting measures to use renewable energy and resources, recycling automobiles and their electronic components or hazardous materials, as well as using sustainable materials and supporting the circular economy (Ray *et al.*, 2024; Tillu *et al.*, 2024). In addition, the effects of the semiconductor crisis, such as reducing working hours (Audi, Daimler, Volkswagen) or temporarily closing some factories (BMW,

Daimler, Ford) (Frieske & Stieler, 2022; Ramani *et al.*, 2022), directly determining the reduction of production costs. Moreover, even in the context in which sales prices have increased, for example, Automobile company Tesla increased the price of its Model 3 vehicle by about $500 due to a shortage of semiconductors (Ramani *et al.*, 2022), the demand for automobiles has continued to grow (Frieske & Stieler, 2022; Ramani *et al.*, 2022). This fact indicates the high level of customer desire to purchase sustainable automobiles, equipped with as many systems based on semiconductors as possible, such as advanced driver-assistance systems (ADAS), engine management and fuel economy, automotive software and cyber security, safety airbags, anti-lock braking systems (ABS), traction control and stability systems, and others (Frieske & Stieler, 2022; Ramani *et al.*, 2022; Deloitte, 2019).

Instead, in the context of the global semiconductor crisis, semiconductor manufacturing companies have focused their attention on ESG controversies and governance issues in the industry. The negative association between ESG performance, as measured by the ESG Controversies Score, and financial performance was attributed to the context of the global semiconductor crisis. Therefore, even though semiconductor manufacturers have been involved in fewer ESG controversies, with a mean score of around 95.77 points compared to automobile manufacturers with a mean score of around 70.05 points, the semiconductor industry has developed its business strategies. Thus, ESG controversies based on historical or ongoing sustainability-linked scandals (Passas *et al.*, 2022) involving companies have been transformed into business opportunities that have led to increased financial performance. The context of the global semiconductor crisis that took shape due to the increase in the level of demand over the production capacity in the context of the SARS-CoV-2 pandemic or other events in the semiconductor industry, such as fires and cold snap (Ochonogor *et al.*, 2023; Frieske & Stieler, 2022; Ramani *et al.*, 2022), has been assimilated to the ideal period for the emergence of ESG controversies, but which can be transformed into business opportunities. Furthermore, the positive association between ESG performance, as measured by the Governance Pillar Score, and financial performance was attributed to the integration of opportunities generated by ESG controversies into management practices. Thus, to generate financial performance in the context of the global semiconductor crisis, semiconductor manufacturers have adopted best management practices in relation to the opportunities generated by ESG controversies.

The most important practical implication is in relation to the stakeholders of the companies. They should consider integrating ESG disclosure into the group of information needed for decision-making. In addition, this study contributes to the development of research on the determining role of sustainable development in generating financial performance in the case of two interconnected economic activities affected by the global semiconductor crisis.

This study was limited to a few analyses and two interconnected economic activities, while a single relationship was addressed in the context of the global semiconductor crisis. Potential future research may include other industries affected by the semiconductor crisis, other measures of ESG disclosure and financial performance, or extending the research period.

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