



The Nexus between Artificial Intelligence and ESG Performance: A Case from Manufacturing Firms of China

Dr. Ayaz Qaiser¹, Muhammad Ali², Muhammad Fahad³, Zara Rafique⁴ & Waseema Batool⁵

¹Grand Asian University, Email: qaiser.ayaz06@gmail.com

²MA Development Studies (IPED), International Institute of Social Studies (ISS), Erasmus University Rotterdam, The Netherlands, Email: muhaqig.ali@gmail.com

³MS Finance Scholar, Institute of Business and Management Sciences, University of Agriculture, Faisalabad, Email: malikxfahad981@gmail.com

⁴Assistant Professor & PhD Scholar, Hassan Murad School of Management, University of Management and Technology, Lahore, Email: zararafique86@yahoo.com

⁵Lecturer (IT), Department of Information Technology, Shaheed Benazir Bhutto University (SBBU), Shaheed Benazirabad, Pakistan.

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Corresponding Author:

Dr. Ayaz Qaiser

Email:

qaiser.ayaz06@gmail.com

ABSTRACT

Improving manufacturing organizations' ESG (Environmental, Social, and Governance) performance is becoming more and more important in the global pursuit of green and sustainable development. AI (Artificial intelligence) has become a vital instrument for manufacturing companies to obtain a driven advantage in sustainability as a result of the growing digital revolution and urgent environmental issues. There is little academic research on the precise effects of artificial intelligence (AI) on the performance of ESG of manufacturing companies. The role of digital technologies in promoting ESG developments has been not extensively explored. The sample consists of Chinese-listed manufacturing companies from 2013–2022. This research study fills the research gap by developing a theoretical framework of how AI affects manufacturing organizations ESG pillars. Regression analysis, a correlation matrix, and descriptive statistics were used by the researcher to examine the data. The results show that the use of AI technology successfully encourages enhancements in manufacturing companies' ESG performance. This research adds to the body of knowledge on improving ESG performance, clarifies the theoretical basis for AI-enabled companies' non-economic performance, and expands the use of organizational dualism theory in novel settings.



Introduction

More nations and businesses are concentrating on improving their environmental, social, and governance (ESG) performance as a result of the increased emphasis on green and sustainable development on a worldwide scale. (Wang et al., 2023; Koseoglu et al., 2022). Manufacturing companies, in particular, are vital to the global economy because they are not only the main producers of industrial goods but also all-encompassing businesses that combine social responsibility, market responsiveness, and technical innovation. In 2023, Serrano-García et al. These businesses must prioritize environmental preservation, social responsibility, and corporate governance enhancements in addition to increasing operational efficiency in the current economic and environmental climate. Xie and Chen (2022). However, businesses run across a number of technological obstacles throughout this process that prevent them from improving their ESG performance. For example, adopting circular economy principles, cutting waste emissions, and increasing energy efficiency frequently need for cutting-edge technology assistance. Chowdhury and associates (2022). Additionally, businesses find it difficult to measure their ESG performance due to the complexity of data gathering and processing. Kuzey and associates (2014). In addition to raising operating expenses, these problems impede the advancement of sustainability.

New approaches to overcoming these technological obstacles are made possible by the advancement of artificial intelligence (AI) technology. Zeng (2024). As a major growth engine, artificial intelligence is turning becoming a vital resource and competitive advantage for businesses of all kinds. Ferrigno and associates (2024). It has a significant impact on organizational procedures and corporate operations. Businesses may use AI to form dynamic capabilities, improve resource efficiency, and play a big part in innovation by promoting precise invention and open cooperation. Jimeno (2019). AI can also help ensure accuracy and transparency in ESG metrics monitoring and reporting.

AI is therefore essential to improving performance of ESG. AI has now permeated production in industry, changing conventional industry models and driving value creation in the future while significantly boosting the global market and social performances.

The World Economic Forum, the EU (European Union), as well as the United Nations have all made it clear that using AI should help achieve sustainable development goals. Linnér & Francisco (2023). As a result, AI's high degree of intelligence and digitization may assist businesses in overcoming problems including low energy effectiveness, shaky innovation foundations, and bottlenecks in transmission of information. An encouraging environment and essential components for enhancing ESG performance in manufacturing companies are provided by Sankaran (2019).

The majority of current research is on how AI affects manufacturing efficiency and company financial performance (Gyau et al., 2024). Fewer studies have looked at how AI impacts ESG performance, especially in the industrial sector (Wang et al., 2024). Although AI offers great promise to help manufacturing companies with their many environmental and social problems, the precise mechanisms and impacts in this area have not yet been well investigated in the literature. By accelerating the deep-integration of artificial intelligence (AI) through manufacturing in the industrial sector and making full use of the clean and low-pollution nature of intelligent technologies, the purpose of this research study is with the purpose of continually revitalising the environment optimisation influence of AI, thereby supporting manufacturing enterprises in accomplishing their objective of reducing emissions from green sources of reducing their carbon footprint. This is in answer to the call made by researchers such as Lv et al. (2023). Existing

research, however, ignores the connection involving AI and the ESG performance of industrial enterprises. Furthermore, large size sample, long series of periods empirical analyses are limited in present research, which mostly employs cross-sectional data or single-case studies. This restriction limits the findings' external validity and generalizability. Furthermore, the data sources and assessment techniques used in current research are limited, making it challenging to capture the nuanced link fully and effectively relating ESG performance and AI.

Following the previous literature, this research analysis uses a dataset that includes 80 A-share manufacturing companies that were listed between 2013 and 2022 on the Shenzhen and Shanghai stock exchanges in China. This allows for a thorough investigation of the ways in which AI affects manufacturing companies' ESG performance. This study contributes just slightly to the body of existing literature. The influence of artificial intelligence (AI) on manufacturers' firm ESG performance in the area of sustainable and green development is explained, thereby extending and enhancing previous research on improving manufacturing enterprises' ESG performance and elucidating the theoretical reasoning behind in what manner AI enhances non-economic performance of businesses.

Theoretical Framework and the Development of Hypotheses

Manufacturing Firms' AI and ESG Performance

On the backdrop of a worldwide push to achieve sustainable development and high-quality economic growth, in addition to placing a high priority on financial returns, businesses are obligated to simultaneously take the initiative to take environmental preservation into consideration, corporate governance, social responsibility, and the active contentment of ESG obligation, as these essential factors that determine durability over time and a competitive edge. Artificial Intelligence (AI) is a digital system that can collect and analyze data, learn and improve performance, comprehend and produce natural language, and carry out reasoning and decision-making activities by imitating human cognitive thought and behavior. A strong instrument for improving ESG performance in businesses is offered by Manser Payne et al. (2021). Additionally, it helps businesses create new knowledge, enhance decision-making, and better satisfy customer wants. Ferrigno and associates (2024).

First off, manufacturing companies' use of AI technology has greatly improved their capacity to extract, process, and evaluate un-structured and non-standardized data, which promotes more efficient information flow both inside and outside the company. In 2021, Zeng et al. Since then, business procedures have been simplified and internal management of organization has been improved due to the speed at which information is shared and products are developed. This has made it possible to adopt effective and sophisticated management within the company. AI is essential to businesses' ability to make choices more quickly and precisely, which raises corporate governance standards over time.

Second, businesses must refrain from shortsighted actions that harm the environment and long-term societal benefits if they are to accomplish long-term development. AI can perform in-depth analyses of data regarding environmental conditions and production processes, enabling businesses to develop and implement more flexible approaches to environmental preservation and climate interventions in a more logical and objective manner. This analytical ability makes it easier to identify climate hazards, improve resource efficiency, and reduce carbon emissions. Li and associates (2024). At the same time, AI improves cross-organizational cooperation among

businesses, lowers the bar for applying environmental protection technologies like energy conservation and environmental governance, and speeds up businesses' green transformation, improving their environmental performance.

Lastly, the ability of manufacturing businesses to achieve long-term success is largely dependent on social responsibility, an intangible asset. AI's deep interpretation and mining capabilities enable businesses to swiftly recognize and describe the value requirements of various stakeholders, such as shareholders, creditors, workers, upstream and downstream businesses, and the general public. This speeds up market response, removes information barriers, and improves the effectiveness of allocating external resources. At the same time, businesses are more aware of their reputation and public image due to the close observation and inspection of many stakeholders, which makes it easier for them to take on a wider range of social duties.

In conclusion, manufacturing companies may use AI to guide their decision-making toward social responsibility, environmental responsibility, and firm corporate governance, which will ultimately improve their ESG performance and lead to Hypothesis 1.

Ha: ESG performance of manufacturing companies is enhanced by AI.

Methodology

Sources of Data

This research study used a multi-channel, multi-source data gathering strategy to guarantee its reliability and integrity. This research study used a multi-channel as well as multi-source data gathering strategy to guarantee its reliability and integrity. The precise procedure for gathering data is as follows: From 2013 to 2022, 800 A-share manufacturing businesses that were listed on the Shanghai and Shenzhen stock markets comprise the study sample. To guarantee sample representativeness and data completeness, companies with serious data shortages and unusual financial situations were removed.

Of these, ESG ratings on the Huazheng and the Wind database provided the ESG performance statistics. This study has a solid foundation like Wind, a top financial data supplier in China, which provides comprehensive, reliable, timely, superior quality data. The authenticity and dependability of patent data are guaranteed by the reputable academic data portal CNRDS. The dependability and diversity of the research data were further increased by obtaining more market and financial data from the Choice Financial Terminal, a popular platform for investment analysis and financial studies that is renowned for its thorough and appropriate financial data.

Following the collection of all data, the following actions were performed: To ensure data accuracy and consistency, rigorous cleaning and preprocessing were first carried out to eliminate outliers and duplicate data. Second, in order to make further analysis and modeling easier, data from various sources were combined into a single study database. Third, to minimize the effect of data bias on the study findings, cross-validation and comparison analysis were carried out to guarantee data reliability and consistency. This study guarantees high-quality and trustworthy data through these meticulous data gathering and processing procedures, offering a strong basis for investigating the connection among the performance of ESG and artificial intelligence of manufacturing companies.

Regression Model

Referring to the research of researchers like Lai et al. (2024), we develop Model (1) established on Hypothesis (a) to investigate the connection relating artificial intelligence and the performance of ESG of manufacturing companies.

$$ESG_{i,t} = \alpha_0 + \alpha_1 AI_{i,t} + \alpha_i Controls_{i,t} + \Sigma Company_{i,t} + \Sigma Year_{i,t} + \varepsilon_{i,t} \quad (1)$$

From model (1), i represents firm, t represents year, ESG_{it} is the ESG performance score of firm i in period t , AI_{it} is the degree of AI of firm i in period t , $Control_{it}$ denotes the control variable, $Company_{it}$, $Year_{it}$ denote firm and year, respectively, and ε_{it} is the random error term.

Variable Description

Dependent Variable

ESG measures are the core of the Huazheng ESG Rating System, a particular framework. It provides extensive coverage, uses scientific evaluation techniques, and upholds timely and high-quality data. In contrast to other ESG ranking systems, the Huazheng system offers more comprehensive and in-depth ESG ratings and data that are reliable and complete.

Additionally, the industry regards its ratings and statistics as authoritative and well-known. The Huazheng ESG rating data from 2013–2022 is used in this study. The ratings are divided into nine categories, ranging from low to high, and firms are ranked from 1 to 9 according to their yearly ESG rating level (Feng et al., 2022).

The better the manufacturing companies' ESG performance, the higher the number.

Independent Variable

The majority of the research now in literature measures AI at the micro level through surveys or patents rather than developing thorough indicators that represent the micro-level AI of businesses, Li and associates (2023). The primary business data, operational circumstances, and management's assessment of the company's future development orientation are all revealed in the annual reports of listed firms. Wang et al. (2021), which offers valuable reference material for comprehending the business strategy and decision-making of the organization. As a result, this study makes use of the AI dictionary that Yao et al. (2024) developed and summarized, which contains 73 AI-related terms. The amount of AI application in that manufacturing company was measured by adding 1 and taking the natural logarithm of the data from annual reports of listed companies, which was evaluated through text analysis to summarize the existences of the words comprised in the AI dictionary in the company's annual report.

Control Variables

The following control variables were used to assure the validity of the study's findings and to acknowledge the impact that other inherent aspects of manufacturing companies have on their ESG performance: size of firm and total ratio of asset return, which reflect the corporation's investment in R&D concentration and asset operation effectiveness; enterprise ownership type, degree of equity concentration, and board size, which have a significant impact on the strategic decision-making of company and response speed; firm leverage and the cash flow uncertainty that prevents

businesses from implementing artificial intelligence, environmental protection, and social responsibility technologies.

Table 1: Lists specific techniques for measuring variables

Table 1. Explanation of variables

Variable	Description	Symbol	Computation Method
Dependent variable	Performance of ESG	ESG	Score on the Huazheng ESG Rating Index
Independent variable	Artificial Intelligence	AI	ln (the total number of AI word frequencies + 1)
	Board Size	BSIZ	The number of directors on the board.
	Return on Assets	ROA	At the end of the period, net profit divided by total assets.
	Cash Flow Level	Cash	Operating Cash Flow divided by Operating Revenue
	Firm leverage	FL	Total Equity/Total Debt

Data Analysis

Descriptive Statistic

The descriptive statistic provides an overview of the data's most important features. Table I below shows the descriptive summary for measuring the impact of environmental sustainability on financial performance.

Table I: Descriptive Summary

Variable	Obs	Mean	S.D	Min	Max
ESG	800	4.010	1.050	1.000	7.250
AI	800	0.740	1.100	0.000	5.570
BSZ	800	8.397	1.522	0.000	18.000
ROA	800	6.647	19.530	-88.81	126.30
Cash	800	0.905	5.140	-137.31	102.10
FL	800	56.80	15.30	0.360	76.80

The descriptive statistics associated with the variables are shown in the table.

Correlation matrix

Correlation matrix appears the connection concerning dependent and independent variable. Its values fall between +1 and -1.

Table II: Correlation matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)
ESG	1					
AI	0.056	1				
BSZ	0.183	0.061	1			
ROA	0.031	-0.042	0.024	1		
Cash	0.031	0.058	0.053	-0.038	1	
FL	0.050	0.079	-0.086	0.085	-0.049	1

The Table displays the correlation matrix among variables.

Regression Analysis

Baseline Regression Results

The empirical results that investigate the connection between artificial intelligence and the environmental, social, and governance determinants of manufacturing companies are shown in Table III. The total number of observations is 800. Using the F-value and the R-squared statistic, the fitness of the model is evaluated. The R squared score is 0.47, demonstrating that the whole variance in the ESG in China can be attributed to independent variable AI. The F-value findings specify that the entire model is significant at the 1% level and is suitable for further examination. AI, BSZ, ROA and Cash have a positive relationship with ESG. Enhancing AI improves the ESF performance of manufacturing firms operating in China. FL and ESG has insignificant relationship.

Hypothesis H1 is supported by the regression findings, which consistently show a strong positive association relating AI and performance of ESG, regardless of whether control factors are included.

Table. III: Regression Analysis

ESG	Coef.	St.Err.	P-value
AI	.061***	.041	.0095
BSZ	-.0136***	.039	.008
ROA	.001**	.021	0.003
Cash	.014*	.088	.073
FL	-.0326	.018	.723
Constant	31.366	4.629***	0
R2	0.47	No of observation	800
F-test	16.95	P > F	0.001***

*This table displays the regression analysis for China. The independent variable is Artificial Intelligence (AI). Board size (BS), return on assets (ROA), cash flow (Cash), and firm leverage (FL) are the variables that served as the study's control variables. Statistically significant at 10%, 5%, and 1% correspondingly are denoted by the symbols *, **, and ***.*

Results and Discussion

Improving the ESG performance of manufacturing corporations takes critical relevance in light of the worldwide drive for green sustainability. AI is a disruptive technology that has been

demonstrated to help businesses make the shift to sustainable development in production and innovation environments (Zhang & Liu, 2023; Jing & Zhang, 2024).

This research study used multivariate analysis in order to evaluate the influence of AI on the ESG of manufacturing enterprises in China. Table III illustrates that AI impacts the ESG performance of manufacturing corporations in China. The outcomes of AI variables align with stockholder theory, indicating that AI initiatives enhance ESG which in turn increase business performance. Previous studies (Jamal et al., 2024; Mohammad & Wasiuzaman, 2021; Jamal et al; 2023; Muslicheh, 2020; Ahmad et al., 2021) have shown a progressive association among ESG criteria and company performance. The institutional theory posits that a business's external and internal environment, together with its corporate culture, is most applicable in attaining entire facets of sustainability. For the sake of this concept, the organization might be likened to an institution with a common goal. The findings of Develle (2021) and Zhang et al. (2022) indicated that the AI component demonstrates substantial performance outcomes. Broadstock et al.(2021) and Muslichah (2020) have researched the influence of AI methods on business value. An effective AI method enhances investor confidence, increasing ESG performance, hence increasing the firm's value. In particular, the promotion influence of AI on the ESG performance of manufacturing businesses is larger in manufacturing organizations that have a high balance of twohanded green innovation and huge size. This detailed knowledge helps customize AI tactics to varied circumstances, boosting the practical usefulness of the findings, Arniati and Muslichah (2023).

The findings indicate that business board size negatively impacts the ESG of Chinese firms. Li et al. (2021) also Mohammad and Wasiuzzaman (2021) confirmed that firm size has a negative link with firm value. The firm's leverage showed insignificant relationship with ESG. The cash of the firm has a statistically significant and optimistic association with ESG. The results indicate that firms with more leverage will achieve better profitability, whereas smaller organizations are expected to exhibit greater productivity.

Conclusion

ESG problems are critical variables to consider in the attainment of the objectives of company. The major aim and objective of this analysis to ascertain the extent of the effect of AI elements on the ESG performance of corporations performing in Malaysia. This study examines the main AI issues that influence ESG performance.

This analysis chose a sample of manufacturing firms listed on the China Stock Exchange from 2013 to 2022. Multivariate analysis was conducted on panel data as part of this inquiry. The study results indicate that AI, Cash, board size, ROA enhance the ESG performance. The firm leverage is insignificantly influencing ESG pillars. The research study results align with previous empirical investigations. Management and policymakers may get advantages from the results of this study, since they specify effective insights. Their resources are administered, and they allocate investments towards ecologically sustainable operations. The state of the economy is going to improve over the course of the coming decades.

Recommendations

Taking into account how various stakeholders might profit from and make good use of these results, this study attempts to better link the research findings with economic realities based on the previously described research conclusions.

Government Level: To create a market and regulatory environment that supports AI-driven innovation, the government should first expedite the extensive use of AI in the manufacturing sector by encouraging the adoption of smart and green manufacturing projects. Second, rather of implementing rules for intelligent transformation that are universally applicable, the government should create regulations that are specific to various industries and firm sizes, with a greater emphasis on supporting SMEs' use of AI technology.

Manufacturing Enterprise Level: To promote digital transformation and attain sustainability, manufacturing firms should aggressively utilize AI. Businesses may improve operational efficiency and business agility while lowering environmental consequences by creating AI programs that are environmentally sustainable.

Limitations and Future Research

It is recommended that future studies use larger datasets from a variety of sectors for comparison analysis in order to increase the thoroughness and generalization of the conclusions drawn. It is also recommended for future research to study the indirect effect between variables. For example moderating effect and mediating effect. By analysis the indirect effect more dimension of ESG and AI will be explored.

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