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Abstract: In the digital economy era, digital transformation is crucial for competitiveness in traditional industries, particularly in manufacturing. This study aimed to examine how digital transformation impacts the manufacturing environment, social responsibility, and corporate governance (ESG), with a focus on the role of senior executive teams. Using empirical analysis of Chinese A-share listed companies from 2010 to 2019, this study found that digital transformation promotes ESG performance in the manufacturing industry. The findings revealed that the educational level, CEO tenure, and professional background diversity of senior management teams moderate this relationship, enhancing ESG performance. This study enriches and expands the existing knowledge system on this topic by integrating theories related to the digital economy and resource-based theories. It provides methodological guidance for the manufacturing industry to improve its environmental, social, and governance performance and achieve rapid development. Additionally, it offers practical suggestions for the government, manufacturing enterprises, and senior executive teams on how to better play their performance in digital transformation and ESG governance. This will assist the manufacturing industry enhance its level of digital transformation and continuously improve its ESG management and governance.

Keywords: digital transformation; manufacturing industry ESG; executive education level; CEO tenure; occupational background heterogeneity

1. Introduction

Since digital technologies have developed, digitalization has transformed societal and economic aspects in the digital era [1]. Digital technology includes communication technologies, cloud computing technologies, artificial intelligence technologies, big data technologies and so on. Because of the growth of conventional businesses spurred by these developments, digital transformation is playing a growing favorable role in establishing long-term economic benefits [2]. Digital transformation refers to the process of rebuilding the core business processes of enterprises and organizations by using the means and concepts of digital technology and realizing the transformation from the traditional business model to digitalization. Digital transformation not only involves the upgrading and updating of technology but also involves changes in the management and organization of enterprises. In China, a series of policies and support mechanisms have been actively introduced, and in-depth plans for the development of digitalization and industrialization have been continuously released. These efforts strengthen digital applications in the manufacturing industry, break through key common technologies, drive the transformation of production methods, and promote high-quality development in the manufacturing industry [3]. Governments around the world have launched development plans [4,5], and
Enterprise digital transformation has become a major factor in the sustainable development of enterprises, which strongly promotes innovation, development, and maintaining inexhaustible power in competition [6].

As the main body of the national economy of each country, the manufacturing industry reflects the wealth creativity and economic strength of a country, and all countries are strengthening the implementation of the strategy of manufacturing power, enhancing the competitive advantage of the manufacturing industry, and promoting high-quality development of the manufacturing industry; and so, countries attach great importance to the digital transformation of the manufacturing industry, and at present, how the manufacturing industry can give full play to the driving role of the elements of the digital transformation, and achieve the environmental, social and governance performance (ESG) enhancement has become a key concern for countries and enterprises [7,8].

Simultaneously, the external environment inevitably influences enterprises' business development, and market competition, as an important external environmental factor, has a crucial impact on innovation activities and the ESG performance of the manufacturing industry [9]. For a successful enterprise, if it wants to achieve future stable economic development, it needs to consider the impact of sustainable development in three aspects: environment, society and economy [10]. Digital transformation has brought a new revolution to the development of the manufacturing industry, but there are fewer studies on the impact of manufacturing digital transformation on ESG and its mechanisms. This study focuses on the relationship between digital transformation and the impact of manufacturing ESG performance and empirically analyzes the moderating effect of characteristics such as the cultural degree of the top management team on manufacturing ESG performance.

The impact of digital transformation on manufacturing ESG has been studied from three aspects through the existing literature. Digital transformation can reduce the carbon risk level of enterprises by enabling emission reduction and efficiency enhancement, optimizing supply chains, and fostering green technology innovation. This effect is more pronounced in companies where environmental regulations are strong, industry competition is fierce, and there is a focus on digital transformation of production processes [11]. Understanding the environmental needs of enterprises and the public based on digital technology, effectively coordinating the interests of different entities in the digital economy to promote green development, formulating practical and effective environmental systems for green development, and ensuring stable and far-reaching green development are crucial [12]. Building a “product platform” is believed to help enterprises enhance competitiveness between business departments and brands during the sales process, boost brand influence through digital platforms, and fulfill social responsibilities [13]. The interaction between digital transformation and corporate social responsibility is mutually reinforcing, as enhancing corporate social responsibility can accelerate corporate digital transformation [14–16]. Using digital Internet technology for job searches can significantly reduce job search costs for workers, create more employment opportunities, improve employment structures, and maintain social stability [17]. Digital transformation provides new development momentum to physical enterprises, optimizing internal control and improving organizational processes and structures [18]. Digital transformation may restructure a company’s strategy and organizational framework; it helps companies better adapt to the rapidly changing digital business environment, maintain a competitive edge and achieve long-term growth [19]. Management’s support for businesses digital transformation and the use of digital technology for digital management can help improve the efficiency and effectiveness of activities within companies so that enterprises can adapt to the changes brought by digital transformation faster [20]. In the era of big data, smaller businesses demand to link their business strategy with digital technology to provide effective corporate governance, serving enterprise strategic decision making, and jointly promoting enterprise development [21]. According to a survey of senior managers, there is an inverted U-shaped relationship between digital technology and environmental performance [22]. The use of digital technologies represented by information and communication technologies (ICT)
can reduce carbon emissions, but overinvestment can lead to huge energy demand, and companies still find it difficult to make an effective return [23], resulting in the “digital transition paradox” [24]. The manufacturing industry also faces significant cost pressures in expanding the use of digital technologies [25]. While there is optimism about the prospects for ESG performance in the manufacturing sector as a result of digital transformation, it is also important to consider the challenges that come with it [26].

The top management team shapes the company’s digital transformation strategy. Recent studies have shown that top managers are organizational change leaders, corporate strategy shapers, and business model innovators [6], and play a key role in digital transformation implementation. Certo et al. [27] found that the decision-making power of top managers affects the implementation and effectiveness of a company’s strategy. Firk et al. [28] and Sun et al. [29]’s empirical studies discussed that the quality of executive characteristics increases corporate social responsibility and improves ESG performance, but intense market competition and instability in the external environment exacerbate managerial, operational, and decision-making risks during digital transformation [22]. The literature [30,31] provides information about the direct positive effect of the executive team possessing resources of value, scarcity, inimitability, and irreplaceability on firms’ ESG performance, but the results of Xu et al. [32] indicate that the executive team with a high education level has a negative effect on ESG performance.

China is well suited for ESG research in the manufacturing sector. The concept of ESG emerged in the West, and current ESG investment practices are mainly concentrated in Europe and the United States. The core idea of the Western ESG system is that corporate management and financial investment should not only consider economic and financial indicators, but also assess the impact of corporate activities and investment behaviors on the environment, society, and a wider range of stakeholders; companies are concerned about environmental impacts, and the fundamental solution to the problem of human capital, employees’ rights and interests, and labor–management conflicts based on the profitability objectives of the company. As the negative spillover effects of the economy on society and the ecosystem become apparent, a wave of environmentalism and socially responsible investment is emerging, and the concept of sustainable development is gradually being formed, with the West following a development path of polluting first and then treating later, and bottom-up, passive formation. China’s active exploration of ESG practice is to better liberate and develop productive forces, enhance and improve people’s livelihoods, and satisfy the people’s aspirations for a better life in socialist modernization. From the perspective of enterprises, a large number of state-owned enterprises practice ESG concepts, not simply pursuing company profits, but more from the perspective of people’s interests, national interests, and social responsibility for the realization of the public interest; and in comparison with the industrialization process of Western developed countries, which has lasted for 200 years, the proportion of traditional industries is still relatively high, and the time for achieving the “double carbon” goal is even tighter and more difficult, which determines that China’s ESG system, like the “double carbon” goal, cannot be completed overnight and is a proactive choice for promoting China’s high-quality development. It provides a valuable historical opportunity for ESG concepts to be put into practice in China. According to the Digital China Development Report [33], as the world’s second-largest economy, China’s digital development is huge, and as the world’s first manufacturing country, exploring the impact of China’s digital transformation on the manufacturing industry’s ESG performance, especially for the sustainable development of the manufacturing industry in developing countries, can provide valuable insights.

Compared with the existing literature, this paper has the following contributions: First, it enriches the study of digital transformation by taking digital transformation of manufacturing industry as an entry point and demonstrates the economic and environmental value of digital transformation in developing countries; second, it extends and validates the improvement of manufacturing ESG performance brought by digital transformation of enterprises through the study of digital transformation of manufacturing industry; third,
it pays attention to the role of the executive team, analyses the digital transformation on manufacturing ESG and the mechanism of executive team moderating role, and found that heterogeneity of management team’s education level, tenure time, and occupational background is an important complementary resource for manufacturing digital transformation to support the development of manufacturing ESG performance. This study will help to broaden the management literature and facilitate the creation of research applicable to a wider range of contexts, and these findings also provide insights into how corporate management and government policymakers can help improve manufacturing ESG performance through digital transformation.

The rest of the article is organized below. Part 1 describes the study’s background, goal, and importance. Part 2 presents the derived hypotheses and theoretical framework. Part 3 examines sample selection, data sources, variable definitions, and establishing specific research models. Sections 4 and 5 introduce the results of the empirical analysis and robustness tests, respectively. Finally, Part 6 offers the study’s purpose for discussion, conclusion, management implications, and further research directions.

2. Background and Hypotheses Derivation

With the continuous development of computer information networks, the concept of the “digital economy”, developed in 1985 by Tapscott, the father of the digital economy, is being expanded into the age of networked intelligence [34]. The digital economy is not only an economic field concept that simply includes the traditional basic electronic communication, electronic information industry, and other fields of the digital information industry, it began to develop into a general term for the economic field composed of industry digitization, informatization, and intelligence. This is a new economic paradigm that has been developed and extended by integrating digital information into various industries [35]. Today, all walks of life are paying increasing attention to the evolution of the digital economy, moving from the conventional economy to the digital economy, which provides external conditions for industrial transformation and development. The manufacturing industry has also continuously strengthened its emphasis on the digital economy, carried out digital transformation, promoted the manufacturing industry to a higher level of informatization and intelligence, and provided an internal impetus for its transformation and development.

Digital transformation is key for enterprises to actively explore new technology fields, innovate high value-added products, and offer high-end services through technology empowerment, ultimately leading to the appreciation of corporate wealth in a digital environment [36]. Qualitative research, such as that by Ritter, suggests that enterprises use digital transformation to transform their models, change their ecological environment systems, and improve their performance [37]. Following most firms’ digital transformation, the proportions of R&D staff and expenditures have significantly improved. The transformation output and innovation efficiency of enterprises have increased significantly, promoting product upgrades and strengthening the connection between enterprises and markets through digital technology, thereby enhancing the innovation ability and practical efficiency of enterprises [38]. Enterprises use digital transformation to improve the efficiency of enterprise communication and learning, reduce the cost of information search and matching, integrate internal and external innovation resources, and promote a more open and collaborative transformation paradigm [39]. By improving dynamic capabilities, management efficiency, and overcoming financing constraints, digital transformation helps enterprises transform products, processes, organizations, and business models, leading to higher transformation and innovation performance. Enterprises can effectively improve their ESG performance through such transformations and innovations [40].

When digital transformation technologies like big data, AI, cloud computing, and the IoT are applied in the industrial field, some intelligent robots have also emerged. They are replacing manual operations of manufacturing workers, improving manufacturing product and service efficiency, reducing manufacturing costs, and significantly minimizing
carbon emissions [41]. A unified and integrated digital management system is established to transform quality management from automation to intelligence, significantly reduce the cost of information gathering, assistance with decisions, and management of operations, while also improving the ESG efficacy rate in the manufacturing business. The digital transformation of an enterprise meets customers’ needs for interprovincial and international businesses, coordinates services, achieves prompt service commitments, enriches business types, and improves the efficiency of manufacturing sales and services [42].

The triple bottom line theory [43] posits that economic responsibility is no longer the sole determinant of an enterprise’s success or failure. An increasing number of enterprises are recognizing the concept of sustainable development and are focusing on environmental and social responsibilities. They are placing greater emphasis on environmental protection, reducing the emission of pollutants and waste gases in the manufacturing industry, controlling the use of natural resources, and addressing public concerns for the environment and society. Therefore, sustainable development is being achieved in the manufacturing industry [44]. Digital transformation can effectively promote environmental responsibility in the manufacturing industry. Digital transformation may significantly enhance the manufacturing industry’s social responsibility performance, changing the industrial governance philosophy away from the conventional “shareholder-centered” strategy and toward one that stresses “corporate social responsibility”. This transformation can enhance the decision-making ability of managers, improve the rationality of their decision making, and change their decision-making mindset, leading the company’s development toward sustainability and improved performance levels.

“Artificial Intelligence for Sustainability” discusses in detail the influence of digital technology and transformation on sustainable development [45]. Kaplan and Zara believe that the COVID-19 epidemic has accelerated and intensified the digitalization of society and further promoted the development of artificial intelligence. The advantages of telecommuting and organizing business meetings have broken through various blockades, and it is not surprising that artificial intelligence has driven the sustainable development of various industries. The research shows how artificial intelligence can be applied to the fashion field to greatly reduce carbon footprints, accurately locate products in the supply chain, effectively reduce inventory, and promote sustainable development in the fashion field. Farhangi believes that smart metering, as the interface between the smart grid and buildings (that is, between energy production and consumption), plays a key role in the digitalization of the energy industry and is the key to sustainability and successful energy transformation. S. Lee and others point out that artificial intelligence and robots can replace human beings to do a lot of work at night in the future, including searching for the best conditions and arranging the workspace, so as to realize the complementary utilization of resources and capabilities and improve the efficiency and sustainability of manufacturing operations. J. Svanberg discussed a decision support algorithm based on machine learning that was applied to the evaluation of important topics in environmental, social, and governance (ESG) dimensions and helped reporting companies determine the most concerned sustainable development performance. This quantitative research method was praised.

In short, digital transformation brings many benefits, such as streamlining business processes, improving operational efficiency, integrating internal and external resources, fostering business model innovation, and promoting industrial structure upgrading. Through the use of digital technology and continuous innovation, the environmental, social, and governance performance levels of enterprises can be effectively enhanced, which in turn promotes manufacturing performance and ESG performance, largely expands the scope of manufacturing operations, and promotes the sustainable development of the manufacturing industry.

**Hypothesis 1 (H1).** Digital transformation plays an important role in enhancing ESG performance in manufacturing.
According to Schultz’s human capital theory, human capital is critical to economic progress in the United States and around the world. Improvements in worker quality, facilitated by human capital investments, have also contributed to long-term economic development, representing a high-return investment. Education and training can improve an individual’s knowledge, skills, and abilities [46]. Human capital is considered as a key component of a company’s core competencies and lasting competitive advantage [47].

The capacity of the senior management team to absorb, interpret, and process information is strongly tied to their degree of learning. A higher-educated senior management team has a greater probability of comprehending digital tools, technologies, and platforms, as well as how to successfully employ digital transformation technology to set up and execute sustainable practices. In addition, highly educated executives are more adaptive and agile in their learning and more used to obtaining novel abilities and knowledge crucial to digital transformation. Transforming knowledge into work and leadership productivity, generating knowledge spillovers, and using these technologies to achieve sustainable performance [48].

The term “enterprise core competitiveness” was proposed by Prahalad et al. [49]. The concept of core competitiveness has not been unified so far, but researchers unanimously agree that core competitiveness is the ability of enterprises to obtain sustained competitive advantage in market competition, and it is the basis for enterprises to win in competition [50]. Core competitiveness theory highlights the need for high-quality human resources that represent the company’s fundamental competitiveness. Executives with a higher level of education are more innovative and imaginative; they may assist some green enterprises in gaining a greater competitive advantage in innovation while also promoting technical progress and company digital transformation [51]. Furthermore, well-educated, high-quality executives better understand their role orientation in achieving sustainable corporate development, which promotes efficient internal controls by increasing management measures to more effectively manage digitization implementation and mitigate the risks associated with its drawbacks [52].

In terms of strategic development in the manufacturing business, the senior executive team is crucial to competitiveness. Executives with greater education levels have quicker technology adaptation, better learning and comprehension skills, and stronger invention abilities, all of which improve ESG performance.

Hypothesis 2 (H2). The education level of the senior management team has a favorable moderating effect on the digital transformation to enhance the ESG performance of the manufacturing sector.

According to the resource-based theory, CEOs with a long average tenure possess four types of corporate strategic capabilities: they are valuable, scarce, difficult to imitate, and irreplaceable. These capabilities are the basis for companies to maintain a competitive advantage and have a direct positive effect on ESG performance [53]. CEOs with longer tenures tend to have a more accurate understanding and market positioning of the manufacturing industry, better cooperation mechanisms with the enterprise team, more effective identification of ESG strategic resources, higher quality and efficiency of strategic decision-making, and more rapid and flexible responses to changes in market conditions [54]. The longer a CEO’s tenure, the more attention is paid to the long-term development of the enterprise, the more cautious they are in making business decisions, and the more conducive they are to the stability of performance [55]. Research of A-share publicly traded businesses in Shanghai and Shenzhen from 2011 to 2019 discovered that CEO tenure may effectively increase company internal control efficiency, which is beneficial to enterprise performance [56]. The digital transformation and development of organizations require tangible and intangible resources as support. In the digital transformation process, enterprises need experienced CEOs to integrate and reconstruct existing and potential internal and external resources [57].
The smooth implementation of digital transformation not only requires enterprises to have rich internal and external resources and strong resource integration abilities but also requires CEOs to have keen opportunity perception ability and efficient information processing ability to make accurate decision-making choices in time to promote the effective implementation and dynamic adjustment of digital transformation. Technological development has accelerated the industrial industry’s digital transformation and innovation. In this context, the CEO of a company is often responsible for determining the manufacturing industry’s strategic direction.

Hypothesis 3 (H3). The longer tenure of a CEO has a favorable controlling influence on the digital transition to enhance the manufacturing industry’s ESG performance.

The upper echelons theory proposed by Hambrick [58] suggests that the professional background of the senior executive team can reflect their psychological characteristics in terms of knowledge, cognition, and values, thus influencing their strategic decision-making, which directly affects the performance of the enterprise or indirectly affects it through strategic choice. Bertrand and Shore [59] explicitly introduced the power of individual managers into the study of firm behavior for the first time, confirming that the power of individual managers affects decision-making behavior and firm performance. Demerjian et al. [60] found that executives with more power tended to prioritize their personal image and reputation, prioritizing the overall interests of the firm over those of the manufacturing industry’s ESG performance development goals of digital transformation initiatives and supporting innovative behaviors such as digital strategy change, while being willing to take risks in the change process. The professional background of the senior management team of high-tech companies increases the transformation input and output of the company [61]. Executives with professional credentials are more likely to be risk-takers for transformation, have a greater capacity for transformation failure, and encourage staff to attempt new ideas than those without professional experiences [62].

The work of the senior management team has a direct impact on psychology and cognition, influencing their attitudes and decision making. For example, executives engaged in R&D strive to discover new technologies, considering them a source of competitiveness [63]. The heterogeneity of the senior management team’s professional background indicates a variety of network resources in different industries. This diversity not only focuses on investment in transformation technology but also helps the organization attract more talent through its network resources in different industries accumulated in the field of R&D, thereby shortening the time from technology development to product launch and better helping new products penetrate the market.

Executives with professional manufacturing backgrounds are more concerned with the future growth of the manufacturing industry, usually to add the amount that is invested in employees and R&D expenditure and foster the progress of digital transformation in the manufacturing industry, thus improving its efficiency. Senior executive team members with environmental professional expertise prioritize environmental preservation. They set the course for corporate green manufacturing actions, enhance the effectiveness of social responsibility policies, and manage resources for digital transformation. At the same time, compared with ordinary managers, members of the executive team with a management career background have a higher level of corporate governance, and the digital transformation gives entity enterprises higher development speeds, which can accelerate the process of enterprise development.

Hypothesis 4 (H4). The heterogeneity of the senior executive team’s professional backgrounds contributes positively to the digital transformation to enhance the manufacturing industry’s ESG performance.

Figure 1 illustrates the schematic theoretical model used in this study.
3. Research Methods and Design

3.1. Sample Selection and Data Sources

To mitigate the effect of the COVID-19 pandemic across three years, China’s A-share listed manufacturing enterprises between 2010 and 2019 were chosen as study subjects based on certain criteria. Samples with missing data were excluded, as were companies with irregular transactions, such as ST & ST* & PT, and delisted companies. To reduce the effect of aberrant data, every one of the continuous variables was handled at 1%. Finally, 2663 sample values were collected. Data for this research was obtained from CSMAR, WIND, and Bloomberg consulting firms. The yearly reports for the aforementioned firms were collected from the Home Information website.

3.2. Variable Definition

3.2.1. Dependent Variables

This study’s dependent variable is the ESG performance of the manufacturing industry, which reflects the overall ESG rating of enterprises at a certain stage. Based on China’s national conditions, the third-party institutional system of environmental, social, and governance indicators for manufacturing in China can be further improved. Therefore, this study draws on successful experiences from the literature and selects relatively mature and authoritative ESG data from Bloomberg Consulting Corporation. The data includes not just the overall ESG score, but also scores for corporate environmental responsibility (E), social responsibility (S), and corporate governance (G).

3.2.2. Independent Variables

Studies on the measurement of DT have included textual analysis and questionnaires. However, questionnaire surveys may suffer from methodological or subjective bias, which is highly likely to lead to inaccurate conclusions. At the same time, the annual reports of listed companies can effectively and accurately reflect the strategic positioning of enterprises, and the terms related to digital transformation will also be reflected in the annual reports of enterprises. Therefore, this study used textual analysis to quantitatively measure the DT of enterprises based on annual report data. The methodological steps were as follows:

1. To construct a proper keyword lexicon for digital transformation, this study combed through the literature of existing studies that used content analysis to measure digital transformation. The results showed that there were two main keywords related to DT: basic digital technology and digital technology application scenarios. Meanwhile, this study compared and screened the digital transformation keywords used in the literature with those published in the China Stock Market and Accounting Research Database. Finally, 76 digital transformation keywords, such as artificial intelligence, blockchain, and cloud computing were compiled.

2. The corporate annual reports of Chinese A-share listed manufacturing enterprises from 2010 to 2019 were assembled through the Python software, and the text content of all corporate annual reports was extracted through Java PDFbox. MD&A is considered one of the most useful disclosures in financial reports, and it contains more accurate and forward-looking corporate information. In light of existing
studies [72], this study concentrated the text analysis on the MD&A sections of the annual reports to form a text master that could be searched using the DT keywords.  

3. The keywords of DT were searched, matched, counted, and summed in the MD&A text database to form the total word frequencies of DT. Finally, the total frequency of occurrence of words collected was divided by the text size of the annual report MD&A and multiplied by 100 to calculate the assessment index of firms’ digital transformation level. The bigger the score, the greater the level of digital transformation in organizations [68,73].

3.2.3. Moderating Variables

Regarding the senior executive team’s education level, drawing on the successful approach of previous studies [29,74], the senior management team with an undergraduate degree or above was selected as the research subject. The higher the education level of senior management team members, the more receptive they are to transformation, and the greater their innovation ability. Therefore, the average education level of the senior management team is considered a moderating variable affecting the ESG performance of the business. For the research, education levels lower than junior college were assigned a value of 1, junior college 2, undergraduate 3, master’s 4, and doctoral and above 5. Finally, the averages were calculated.

CEO tenure refers to the length of time that the CEO holds the current position, specifically from the start of their tenure until the end of the research period. CEO tenure can be measured by the number of months or years in office [55]. In this paper, a count of months is used to calculate the CEO’s term of office, and a count of months of CEO’s incumbency is calculated through the sample enterprise report.

The heterogeneity of the senior management team’s professional background refers to differences in the professional backgrounds of senior managers. The professional background of senior managers determines their varying cognitions and preferences regarding the strategic focus and risk of the enterprises, which affects the efficiency of the senior managers as well as the whole team and the type of strategy adopted. Senior managers are inevitably influenced by their original work backgrounds and experience when making strategic decisions. For example, senior managers with R&D backgrounds tend to develop innovative strategies, while those with environmental, social, and management backgrounds tend to develop innovative strategies for environmental, social, and corporate governance to improve enterprises’ comprehensive ESG performance. This study uses the Herfindahl Index to calculate the heterogeneity of executives’ professional backgrounds [75].

3.2.4. Control Variables

To reduce the influence of any additional possible variables, our research consulted the literature [76,77]. The following five control variables from different aspects were selected: operating income growth rate, asset-liability ratio, proportion of independent directors, ownership concentration, and board size. Additionally, the year was controlled for. The industry was not controlled for because the manufacturing industry was selected.

Explanations for all variables are shown in Table 1.

Table 1. Variable names and definitions.

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Variable Name</th>
<th>Variable Code</th>
<th>Variable Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variables</td>
<td>ESG performance of manufacturing industry</td>
<td>ESG</td>
<td>Bloomberg ESG score</td>
</tr>
<tr>
<td>Independent variables</td>
<td>Digital transformation</td>
<td>DT</td>
<td>(Sum of the related word frequency in the annual report/text length of the annual report MD&amp;A) × 100</td>
</tr>
</tbody>
</table>
Table 1. Cont.

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Variable Name</th>
<th>Variable Code</th>
<th>Variable Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderating variables</td>
<td>Education Level of executive team</td>
<td>EL</td>
<td>The degree lower than junior college is 1, junior college is 2, undergraduate is 3, master’s is 4, doctoral and above is 5. Use the mean.</td>
</tr>
<tr>
<td></td>
<td>CEO tenure</td>
<td>CT</td>
<td>Number of months in office</td>
</tr>
<tr>
<td></td>
<td>Heterogeneity of executive team’s professional backgrounds</td>
<td>HEB</td>
<td>Herfindahl Index</td>
</tr>
<tr>
<td>Control variables</td>
<td>Growth</td>
<td>Growth</td>
<td>Operating income growth rate</td>
</tr>
<tr>
<td></td>
<td>Solvency</td>
<td>Lev</td>
<td>Total liabilities at the end of the year/total assets at the end of the year</td>
</tr>
<tr>
<td></td>
<td>Proportion of independent directors</td>
<td>Indep</td>
<td>Number of independent directors/number of board of directors</td>
</tr>
<tr>
<td></td>
<td>Ownership concentration</td>
<td>Top10</td>
<td>Shareholding ratio of top ten shareholders</td>
</tr>
<tr>
<td></td>
<td>Board size</td>
<td>Board</td>
<td>Number of Board of Directors</td>
</tr>
<tr>
<td></td>
<td>Annual effect</td>
<td>Year</td>
<td>Year dummy variable</td>
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</tbody>
</table>

3.2.5. Model Construction

In order to back up Hypothesis 1, which claims that digital transformation enhances the manufacturing industry’s ESG, a regression model (Equation (1)) was developed to account for the yearly impact. The model tested the relationship between digital transformation and ESG performance. If $\beta_1$ is positive and passes the significance test, it suggests that digital transformation improves enterprise ESG performance, which supports Hypothesis 1.

$$\text{ESG}_t = \beta_0 + \beta_1 \text{DT}_t + \sum \text{Control}_t + \lambda t + \epsilon_t$$

To further verify the moderating mechanism of the top management team’s education level, CEO tenure, and the heterogeneity of the top management’s professional background on the impact of digital transformation on enterprise ESG performance, the interaction term and moderating variable of digital transformation were added to the regression model. Subsequently, the following models were constructed:

$$\text{ESG}_t = \beta_0 + \beta_1 \text{DT}_t + \beta_2 \text{EL}_t + \beta_3 \text{DT}_t \times \text{EL}_t + \sum \text{Control}_t + \lambda t + \epsilon_t$$  (2)

$$\text{ESG}_t = \beta_0 + \beta_1 \text{DT}_t + \beta_2 \text{CT}_t + \beta_3 \text{DT}_t \times \text{CT}_t + \sum \text{Control}_t + \lambda t + \epsilon_t$$  (3)

$$\text{ESG}_t = \beta_0 + \beta_1 \text{DT}_t + \beta_2 \text{HEB}_t + \beta_3 \text{DT}_t \times \text{HEB}_t + \sum \text{Control}_t + \lambda t + \epsilon_t$$  (4)

In Model (2), if the value of the coefficient B is greater than 0 and is statistically meaningful, and $\beta_1$ is positive and statistically significant, it implies that the more advanced the education level of the upper management, the greater the improvement in the enterprise’s ESG performance through digital transformation. Thus, Hypothesis 2 was established. Models (3) and (4) are explained in the same way as Model (2) and do not need repetition.

Here, ESG represents the dependent variable of ESG performance in the manufacturing industry, DT is the independent variable of digital transformation, EL is the moderating variable of executive education level, CT represents the moderating variable of CEO tenure, HEB represents the moderating variable of executive occupational background heterogeneity, Control represents the control variables, $\beta_1$ to $\beta_3$ represent the coefficients of each variable, t is the research year, and $\epsilon$ is the random error term.
4. Results

4.1. Descriptive Statistics

Table 2 shows the descriptive statistics for all variables. The average ESG index was 2.014, and the median was 1.983, showing that manufacturing businesses’ ESG performance was subpar. The greatest and lowest values were 5.207 and 0.868, indicating substantial heterogeneity in ESG skills among the investigated businesses. In regard to digital transformation, the group of enterprises’ mean value was 22.80, the standard deviation was 30.67, the median value was 14.00, the smallest number was 0, and the highest number was 369, suggesting a relatively low degree of digital transformation with a wide range. The senior management team’s educational level averaged 3.428, with a standard deviation of 0.443. The lowest number was 2, the standard deviation was 3.478, and the highest was 4.357. More than half of the businesses surveyed had a medium level of education. The average value of CEO tenure was 5.112, and CEO stability of the sample companies varied greatly from 0 to 16.67. The mean value of the heterogeneity of the senior management team’s professional background was 0.677, ranging from 0.215 to 0.833. The heterogeneity of the professional background varied significantly. Additionally, in the selection of variables, fair and reasonable criteria are adopted to ensure that there are no outliers or indicators in the range of selected variables that are inconsistent with the premise of the regression model. Overall, among the many listed manufacturing companies in China, there are significant differences in the degree of digital transformation, consistent with descriptions in the literature [78]. The sample data used in this study met these criteria.

Table 2. Descriptive statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESG</td>
<td>2663</td>
<td>2.014</td>
<td>1.983</td>
<td>0.591</td>
<td>0.868</td>
<td>5.207</td>
</tr>
<tr>
<td>DT</td>
<td>2663</td>
<td>22.80</td>
<td>14.00</td>
<td>30.67</td>
<td>0</td>
<td>369</td>
</tr>
<tr>
<td>EL</td>
<td>2663</td>
<td>3.428</td>
<td>3.478</td>
<td>0.443</td>
<td>2</td>
<td>4.357</td>
</tr>
<tr>
<td>CT</td>
<td>2663</td>
<td>5.112</td>
<td>4.500</td>
<td>3.745</td>
<td>0</td>
<td>16.67</td>
</tr>
<tr>
<td>HEB</td>
<td>2663</td>
<td>0.677</td>
<td>0.698</td>
<td>0.0988</td>
<td>0.215</td>
<td>0.833</td>
</tr>
<tr>
<td>Lev</td>
<td>2663</td>
<td>0.412</td>
<td>0.412</td>
<td>0.188</td>
<td>0.0412</td>
<td>0.856</td>
</tr>
<tr>
<td>Board</td>
<td>2663</td>
<td>8.947</td>
<td>9.000</td>
<td>1.691</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Gro</td>
<td>2663</td>
<td>−0.491</td>
<td>−0.149</td>
<td>5.189</td>
<td>−70.93</td>
<td>22.29</td>
</tr>
<tr>
<td>Indep</td>
<td>2663</td>
<td>0.373</td>
<td>0.333</td>
<td>0.0588</td>
<td>0.250</td>
<td>0.625</td>
</tr>
<tr>
<td>Top10</td>
<td>2663</td>
<td>59.97</td>
<td>59.830</td>
<td>15.22</td>
<td>21.22</td>
<td>92.34</td>
</tr>
</tbody>
</table>

4.2. Correlation Analysis

Table 3 shows the relationship analyses of the samples. The results showed a substantial positive connection between the independent variable, manufacturing digital transformation (DT), and the dependent variable, ESG, with a correlation value of 0.047 (significant at the 1% level). This validates Hypothesis 1, which states that digital transformation raises the degree of ESG in the manufacturing business. The VIFs were less than three, suggesting that multicollinearity was insignificant for the study’s main outcome.

Table 3. Correlation analysis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>ESG</th>
<th>DT</th>
<th>EL</th>
<th>CT</th>
<th>HEB</th>
<th>Lev</th>
<th>Board</th>
<th>Gro</th>
<th>Indep</th>
<th>Top10</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESG</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT</td>
<td>0.047 ***</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EL</td>
<td>0.108 ***</td>
<td>0.140 ***</td>
<td>1.000</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>0.045 **</td>
<td>0.026</td>
<td>−0.064 ***</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEB</td>
<td>0.028</td>
<td>0.070 ***</td>
<td>0.124 ***</td>
<td>−0.102 ***</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lev</td>
<td>0.233 ***</td>
<td>0.021</td>
<td>0.120 ***</td>
<td>−0.001</td>
<td>−0.023</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Board</td>
<td>0.087 ***</td>
<td>−0.080 ***</td>
<td>0.099 ***</td>
<td>0.041 ***</td>
<td>−0.079 ***</td>
<td>0.164 ***</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gro</td>
<td>0.018</td>
<td>−0.009</td>
<td>0.027</td>
<td>0.013</td>
<td>0.026</td>
<td>−0.074 ***</td>
<td>−0.019</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indep</td>
<td>−0.002</td>
<td>0.038 *</td>
<td>0.033 *</td>
<td>0.025</td>
<td>0.027</td>
<td>0.037 *</td>
<td>−0.378 ***</td>
<td>0.019</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Top10</td>
<td>0.032 *</td>
<td>−0.023</td>
<td>0.043 **</td>
<td>−0.197 ***</td>
<td>0.055 ***</td>
<td>−0.036 *</td>
<td>−0.050 ***</td>
<td>0.052 ***</td>
<td>0.056 ***</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Notes: *, **, and *** in the table represent significance at the 10%, 5%, and 1% levels, respectively.
4.3. Regression Analysis

For the empirical analysis, a fixed-effects model [79] was used based on the Hausman test findings ($p$-value < 0.05) to account for yearly effects. Table 4 shows the regression analysis findings. Column (1) indicates a 0.0017 coefficient for digital transformation; it is obviously at the level of 1%, indicating that digital transformation improves the ESG performance of manufacturing businesses. Thus, Hypothesis 1 is supported.

Table 4. Regression analysis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1) ESG</th>
<th>(2) ESG</th>
<th>(3) ESG</th>
<th>(4) ESG</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT</td>
<td>0.00170 ***</td>
<td>0.00145 **</td>
<td>0.00156 ***</td>
<td>0.00142 **</td>
</tr>
<tr>
<td>EL</td>
<td>0.0284</td>
<td>(0.62)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT × EL</td>
<td>0.00279 ***</td>
<td></td>
<td>(3.33)</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>0.000565</td>
<td>(0.22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT × CT</td>
<td>0.000289 **</td>
<td></td>
<td>(3.21)</td>
<td></td>
</tr>
<tr>
<td>HEB</td>
<td>0.0125</td>
<td>(0.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT × HEB</td>
<td>0.0134 ***</td>
<td></td>
<td>(3.31)</td>
<td></td>
</tr>
<tr>
<td>Lev</td>
<td>0.0354</td>
<td>(0.38)</td>
<td>0.0443</td>
<td>0.0423</td>
</tr>
<tr>
<td>Board</td>
<td>−0.0278 **</td>
<td>−0.0285 **</td>
<td>−0.0273 **</td>
<td>−0.0278 **</td>
</tr>
<tr>
<td>Gro</td>
<td>0.00329 *</td>
<td>0.00307 *</td>
<td>0.00324 *</td>
<td>0.00339 *</td>
</tr>
<tr>
<td>Indep</td>
<td>−0.513 *</td>
<td>−0.496</td>
<td>−0.474</td>
<td>−0.539 *</td>
</tr>
<tr>
<td>Top10</td>
<td>0.00390 ***</td>
<td>0.00371 **</td>
<td>0.00382 **</td>
<td>0.00381 **</td>
</tr>
<tr>
<td>_cons</td>
<td>1.884 ***</td>
<td>1.801 ***</td>
<td>1.864 ***</td>
<td>1.886 ***</td>
</tr>
<tr>
<td>Firm</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>2663</td>
<td>2663</td>
<td>2663</td>
<td>2663</td>
</tr>
<tr>
<td>R²</td>
<td>0.259</td>
<td>0.263</td>
<td>0.262</td>
<td>0.263</td>
</tr>
</tbody>
</table>

Note: *** $p$ < 0.01, ** $p$ < 0.05, * $p$ < 0.1.

Column (2) shows a coefficient for digital transformation (DT) of 0.00145, which is significant at the 5% level. Furthermore, the interaction coefficient between digital transformation (DT) and senior management team education level (EL) is 0.00279, showing that executive education level has a positive moderating effect on the impact of digital transformation on ESG levels. Thus, Hypothesis 2 is supported.

In Column (3), the coefficient for digital transformation (DT) is 0.00156 (significant at the 1% level), and the interaction term coefficient between digital transformation (DT) and CEO tenure (CT) is 0.000289, significant at the 5% level. This suggests that CEO tenure improves the effect of digital transformation (DT) on ESG levels. Therefore, Hypothesis 3 is supported.

In Column (4), the coefficient for digital transformation is 0.00142, significant at the 5% level. Moreover, the interaction coefficient between digital transformation (DT) and top management team career background heterogeneity (HEB) indicates 0.0134, which is meaningful at the 1% level. These phenomena indicate that the heterogeneity of the career backgrounds of senior management teams can help enterprises better achieve ESG goals.
and improve ESG performance in the digital transformation of manufacturing enterprises. Thus, Hypothesis 4 is confirmed.

4.4. Robustness Check

To test the robustness of the empirical results, this study refers to other studies and uses the following two approaches for validation:

4.4.1. Substitution of Dependent Variables

Referring to Xue et al., this study selected three sub-scores in the ESG ratings of Huazheng as alternative variables to the total ESG score: environmental responsibility (ESG_E), social responsibility (ESG_S) and governance (ESG_G). Table 5 displays the results, with columns 2–4 showing the regression results without control variables. When the dependent variable is ESG_G, the result is significantly positive at the 5% level. When the dependent variables are ESG_E and ESG_S, the results are significantly positive at the 1% level. When the control variables are added, the regressions between DT and ESG_E and ESG_S are significantly positive at the 1% level. The regressions between DT and ESG_G are significantly positive at the 5% level. The results are consistent with the prior results.

Table 5. Substitution of dependent variables.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT</td>
<td>0.0404***</td>
<td>0.0312***</td>
<td>0.0134**</td>
<td>0.0414***</td>
<td>0.0318***</td>
<td>0.0153**</td>
</tr>
<tr>
<td></td>
<td>(4.99)</td>
<td>(3.64)</td>
<td>(2.52)</td>
<td>(5.13)</td>
<td>(3.68)</td>
<td>(2.90)</td>
</tr>
<tr>
<td>Lev</td>
<td>0.706</td>
<td>−0.137</td>
<td>−2.890**</td>
<td>(0.50)</td>
<td>(−0.09)</td>
<td>(−3.10)</td>
</tr>
<tr>
<td>Board</td>
<td>−0.323*</td>
<td>−0.164</td>
<td>−0.0739</td>
<td>(−2.28)</td>
<td>(−1.08)</td>
<td>(−0.80)</td>
</tr>
<tr>
<td>Gro</td>
<td>0.0358</td>
<td>0.0340</td>
<td>0.00984</td>
<td>(1.70)</td>
<td>(1.50)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>Indep</td>
<td>−9.016*</td>
<td>−0.748</td>
<td>−6.396**</td>
<td>(−2.40)</td>
<td>(−0.19)</td>
<td>(−2.60)</td>
</tr>
<tr>
<td>Top10</td>
<td>0.0781***</td>
<td>0.0272</td>
<td>0.0570***</td>
<td>(4.65)</td>
<td>(1.52)</td>
<td>(5.19)</td>
</tr>
<tr>
<td>_cons</td>
<td>8.455***</td>
<td>21.73***</td>
<td>44.54***</td>
<td>9.597***</td>
<td>21.89***</td>
<td>45.19***</td>
</tr>
<tr>
<td></td>
<td>(24.10)</td>
<td>(58.36)</td>
<td>(193.17)</td>
<td>(3.69)</td>
<td>(7.88)</td>
<td>(26.58)</td>
</tr>
<tr>
<td>Firm</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>2663</td>
<td>2663</td>
<td>2663</td>
<td>2663</td>
<td>2663</td>
<td>2663</td>
</tr>
<tr>
<td>R2</td>
<td>0.185</td>
<td>0.081</td>
<td>0.112</td>
<td>0.200</td>
<td>0.084</td>
<td>0.137</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: ***p < 0.01, **p < 0.05, *p < 0.1.

4.4.2. Two-Stage Least Squares (2SLS) Test

This study uses fixed-effects regression to explore the influence mechanism between digital transformation and ESG in manufacturing. To assess the accuracy of the above results, a two-stage least squares (2SLS) approach was used. Considering potential bias from missing variables and endogeneity issues, the tool variable chosen was the Lag Phase (LDT) of the Digital Transformation (DT) [80].

The first-stage model of the 2SLS is represented by Equation (5), and the second-stage model is represented by Equation (6).

\[
DT = \beta_0 + \beta_1 LDT + \sum \text{Control} + \sum \text{Year} + \epsilon 
\]  
\[
ESG = \beta_0 + \beta_1 DT + \sum \text{Control} + \sum \text{Year} + \epsilon 
\]  

Here, LDT represents the one-period lagged data of DT. Table 6 shows the regression findings for the 2SLS. In the initial phase (second column), the regression coefficient among
DT and LDT is 0.506 (significant at 1%). In the 2nd phase (third column), following the first stage’s simulation analysis of DT and LDT, the manufacturing ESG performance’s regression coefficient is 0.00392 (significant at 1%). In addition, the tool variable is found to be statistically significant and to fit the requirements of weak instrumental variables and non-identifiability, as shown by the value obtained at Cragg–Donald Wald F-statistic of 423.89 with a p-value of 0.000, confirming its appropriateness. These findings suggest that, even after accounting for endogeneity difficulties, digital transformation remains strongly and positively connected with the manufacturing industry’s ESG performance, hence supporting Hypothesis 1.

Table 6. Robustness test regression analysis.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>First Stage</th>
<th>Second Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DT</td>
<td>ESG</td>
</tr>
<tr>
<td>LDT</td>
<td>0.506 ***</td>
<td>0.00392 ***</td>
</tr>
<tr>
<td>DT</td>
<td>(20.59)</td>
<td>(3.56)</td>
</tr>
<tr>
<td>Lev</td>
<td>16.63 ***</td>
<td>−0.0953</td>
</tr>
<tr>
<td></td>
<td>(3.40)</td>
<td>(−0.84)</td>
</tr>
<tr>
<td>Board</td>
<td>−0.685</td>
<td>−0.0275 *</td>
</tr>
<tr>
<td></td>
<td>(−1.42)</td>
<td>(−2.53)</td>
</tr>
<tr>
<td>Gro</td>
<td>0.0868</td>
<td>0.00138</td>
</tr>
<tr>
<td></td>
<td>(1.23)</td>
<td>(0.86)</td>
</tr>
<tr>
<td>Indep</td>
<td>−16.21</td>
<td>−0.140</td>
</tr>
<tr>
<td></td>
<td>(−1.26)</td>
<td>(−0.48)</td>
</tr>
<tr>
<td>Top10</td>
<td>−0.0802</td>
<td>0.00515 ***</td>
</tr>
<tr>
<td></td>
<td>(−1.30)</td>
<td>(3.68)</td>
</tr>
<tr>
<td>Constant</td>
<td>16.10</td>
<td>1854</td>
</tr>
<tr>
<td></td>
<td>(1.77)</td>
<td>0.228</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>N</td>
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<td>1854</td>
</tr>
<tr>
<td>R²</td>
<td>0.446</td>
<td>0.228</td>
</tr>
</tbody>
</table>

Underidentification test p-value 0.000
Cragg-Donald Wald F statistic 423.89

5. Discussion and Conclusions

5.1. Discussion

As digital technology advances and matures, businesses face the issue of digital transformation. However, due to company management’s shortsightedness and externalities, the effect of digital transformation on manufacturing ESG might vary greatly. For instance, several studies have discovered that digital transformation successfully boosts the performance of manufacturing ESG [79], others argue that for non-high-tech manufacturing, digital transformation might not contribute to ESG and could lead to the “innovation illusion,” of digital transformation, resulting in a greater waste of resources [81]. Therefore, the influence of the digital transformation on manufacturing ESG necessitates a thorough and multifaceted strategy. This study has an in-depth understanding of the specific effect of digital transformation on ESG, providing insights into ESG sustainable development in China’s manufacturing industry amid digital transformation.

Digital transformation is a hot topic that all walks of life pay close attention to. Scholars generally agree that digital transformation can enhance corporate social responsibility by improving corporate image [82], accelerating environmental performance [83], and realizing talent knowledge integration [84]. While several studies [85] have concentrated on the short-term effects of digital transformation on ESG, the present research stresses the complex, comprehensive, and long-term nature of this impact. The results of this research
indicate that digital transformation plays a positive role in improving ESG performance in manufacturing.

These studies illustrate the benefits of digital transformation for the economy, society, and environment by using a more thorough methodology and more empirical data. The empirical tests, which employ a fixed-effects model, demonstrate that China’s manufacturing sector’s digital transformation can significantly improve ESG performance, bolstering the country’s resolve and confidence to move more quickly toward digital transformation. These findings align with those of recent empirical studies. For example, Vimal et al. [86] suggested that digital transformation has bolstered the sustainability and resilience of the manufacturing industry chain, optimizing the allocation of resources and accelerating environmental improvement toward carbon neutrality. Eyupoglu [87] highlighted that social and governance performance can enhance shareholder value, thereby impacting ESG performance. Paolone [88], using Italian listed companies, found that governance levels have a significant impact on corporate value.

Additionally, based on the upper echelons theory, human capital theory, and resource-based theory, this research introduces the moderating variables of executive education level, CEO tenure, and heterogeneity of professionals. This paper explores the path of actively implementing digital transformation to achieve ESG performance development in the manufacturing industry, using its executive team resources to deal with various problems and obstacles in the process of digital transformation, and contributing to the sustainable creation of digitalization. Thus, executive teams and their resources are important complementary resources for manufacturing digitization, and digital transformation provides a key driver to effectively contribute to the development of ESG performance in manufacturing. This study further found that in the context of the digital economy, manufacturing companies need to place a high priority on the acquisition of top managerial talent, who are an important force and valuable asset for organizations, and who can drive the realization of digital transformation, thereby contributing to the improvement of manufacturing ESG performance and sustainable corporate development. Sultan et al. [89] emphasized the crucial role of top management teams in value creation and organizational success, using their power resources to address digital transformation concerns while adding to the long-term generation of value. Shin [90] shown that senior management teams may use digital leadership to accomplish long-term ESG objectives by incorporating digital transformation into the business’s long-term expansion goals, purposes, and tactics, and by creating worldwide digital development plans.

5.2. Research Conclusions

This research uses samples from China’s A-share-listed manufacturing businesses from 2011 to 2019 to investigate the influence of digital transformation on manufacturing ESG performance. Simultaneously, it considers the education level of executives, CEO tenure, and the heterogeneity of professional and technical backgrounds as moderating variables. The following conclusions were drawn:

(1) Digital transformation positively affects ESG manufacturing performance. Through regression analysis, it has been found that digital transformation has had a beneficial effect on the growth of ESG performance in the manufacturing business. This impact is represented by strengthening digital transformation, increasing the fusion of the Internet, big data, AI, and manufacturing, enhancing product intelligence, reducing energy consumption, increasing energy efficiency, and promoting harmonious coexistence with nature. On the social side, it improves the comprehensive quality of executives and employees, enhances product and service governance, promotes social responsibility, and increases social contributions. In terms of corporate governance, it innovates organizational structure, increases information disclosure, strengthens internal controls, and improves business performance.

(2) The greater the education level of CEOs, the better the adjustment impact on manufacturing ESG. Well-educated executives are core elements of enterprises that gain a
competitive advantage. They can actively adapt to digital transformation technologies and processes, as well as use this knowledge and technology rapidly and efficiently, resulting in tangible advantages for productive activities and knowledge creation. They are also mindful of their responsibility for the business’s future growth and supervise the digital process to prevent management myopia behavior from affecting decision making and strategic direction.

(3) A longer CEO tenure has a positive moderating effect on manufacturing ESG. CEOs with longer average tenures possess valuable, scarce, difficult-to-imitate, and irreplaceable resources in terms of corporate strategic capabilities. Their understanding of the manufacturing industry and market positioning is accurate, and their cooperation mechanism with the enterprise team is better. Running-in has effectively improved the identification of ESG strategic resources, the decision making of competitive strategies, and the quality and efficiency of the implementation of strategic decisions.

(4) Heterogeneity in executives’ professional and technical backgrounds positively regulates ESG in the manufacturing industry. The heterogeneity of the top management team’s professional background suggests that it has a variety of industry connection resources, which can efficiently and quickly obtain valuable decision-making reference information from various professional backgrounds. This heterogeneity has a positive impact on digital transformation to improve the ESG performance of enterprises.

5.3. Research Implications

From a theoretical standpoint, in the age of digital information, economic development not only pursues high economic benefits but also emphasizes sustainable development. Digital transformation and ESG in manufacturing are current research hotspots. This work contributes to the theoretical comprehension of the influence of digital transformation on ESG in manufacturing. By summarizing and utilizing existing research results, this study explores the relationship and influence between digital transformation and ESG in manufacturing, enhancing relevant theories to a certain extent.

This paper selects recent manufacturing data for empirical research. The data selection is rich in science, and the timeliness is strong, from the economic, social, and environmental aspects of the three aspects of a comprehensive exploration of the relationship between the digital transformation and the manufacturing industry, such as the relationship between the digital transformation and the manufacturing industry’s ESG and the impact, avoiding the limitations of single-factor research, and enriching the digital transformation of the manufacturing industry on the impact of the three aspects of the ESG of the relevant theories. Based on the digital economy theory, upper echelons theory, and human capital theory, this research examines the regulatory function of education level, CEO tenure, and the heterogeneity of vocational and technical backgrounds in the connection among digital transformation and ESG in the manufacturing industry. By integrating relevant theories and expanding the existing knowledge system, this study provides a new research perspective in this field.

In terms of practical impact, China’s digital transformation of the manufacturing industry and ESG ratings started later compared to developed countries. Although there has been obvious growth in recent years, the transformation journey remains challenging, and many enterprises still face difficulties in transformation. The following suggestions can be made based on the research presented in this study.

(1) For enterprises: First, the manufacturing industry should formulate a digital transformation development strategy and improve relevant ESG promotion policies to build a dual competitive advantage suitable for the manufacturing industry. The Chinese government has issued various policies such as the Environmental Protection Law and the overall layout planning of digital China construction. Manufacturing enterprises must understand and respond to policies introduced in a timely manner. Furthermore, top management teams must be prepared for a crisis. Second, digital innovation and transformation are high-tech processes and typically require high-level researchers.
Businesses can keep excellent managers by signing over-time agreements; and eliminate “information islands”; foster the incorporation of new-generation technologies for digital transformation like artificial intelligence, digital twins, and digital currency into manufacturing production; innovate high-quality digital technology application scenarios; and use digital technology to improve the total factor productivity of the manufacturing industry through technology platforms such as IoT and big data. Raw materials, energy, consumer demand, and other information should be monitored to ensure efficient resource allocation and a smooth supply chain and further promote the development of the manufacturing industry. Third, young and highly educated personnel should be selected to join the ranks of senior managers in enterprises, and the proportion of senior executives with scientific engineering and R&D backgrounds in the team should be increased. Priority should be given to executive education, career development, and training to meet the needs of the continuous development of the digital age, promote career development within the organization, and meet the specific needs of the company in the digital space.

For the government: Manufacturing digital transformation efforts require more financial and technical backing. Government decision-makers should implement effective measures to promote digital transformation investment and provide targeted incentives, such as manufacturing digital transformation plans. These activities not only promote the longevity and adaptability of manufacturing growth in the face of obstacles like the COVID-19 epidemic and worldwide threats, but they also secure the continued existence of the manufacturing industry.

For management. To foster technological change and ESG performance, it is critical to raise digital knowledge and thinking among employees. First, top management team managers should have a vision of organizational digital transformation and understand its importance for continuous competition. They have to utilize their influence to help businesses capitalize on the possibilities created by the digital era. Second, Senior management team leaders need to fully understand the theory of digital transformation and have a sense of transformation. According to research [90], managers are capable of guiding their organizations in developing a culture of business, structure of operations, and management teams that are appropriate for the digital era.

In addition, this study selected listed Chinese manufacturing companies as the research subjects because China’s digital transformation and innovation have garnered considerable attention in recent years [91–94]. China’s digital transformation and innovations are seen as representative examples in this context. By focusing on China’s listed manufacturing companies, the study’s results offer more comprehensive information and research value.

5.4. Limitations and Future Research Directions

Although the present study reveals important findings, it has several limitations. First, it exclusively examines listed companies in China’s manufacturing industry, overlooking the applicability to non-listed companies and lacking comparative analyses. Moreover, the findings are specific to China’s manufacturing industry, and the conclusions drawn may be different in the manufacturing industries of other countries. Second, the study focused on variables related to executive education level, CEO tenure, and professional and technical backgrounds to assess the adjustment mechanism, neglecting other stakeholders. Future research could supplement the theoretical framework to include additional perspectives.

Author Contributions: Formal analysis, Data curation and drafting, Q.Y.; investigation, methodology, review, and editing, S.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.
Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

References


13. Perlangeli, G.; Rea, A. The Industry 4.0, the corporate social responsibility and the impacts of brand in the digital transformation. *Int. J. Mark. Stud.* **2021**, *13*, 54. [CrossRef]


62. Choi, I.; Chung, S.; Han, K.; Pinsonneault, A. CEO risk-taking incentives and it innovation: The moderating role of a CEO’s risk-related human capital. *MIS Q.* 2021, 45, 2175–2192. [CrossRef]
64. Sun, S.; Guo, L. Digital transformation, green innovation and the Solow productivity paradox. *PloS ONE* 2022, 17, e0270928. [CrossRef]
74. Liu, Y.; Bian, Y.; Zhang, W. How does enterprises’ digital transformation impact the educational structure of employees? Evidence from China. *Sustainability* 2022, 14, 9432. [CrossRef]
80. Gao, Y.; Jin, S. Corporate nature, financial technology, and corporate innovation in China. *Sustainability* 2022, 14, 7162. [CrossRef]


93. Lu, Q.; Deng, Y.; Wang, X. The impact of China’s green credit policy on enterprise digital innovation: Evidence from heavily-polluting Chinese listed companies. *China Financ. Rev. Int.* 2023, 14, 103–121, ISSN 2044-1398. [CrossRef]


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