Literature review: Industry 5.0. Leveraging technologies for environmental, social and governance advancement in corporate settings

Abstract

Purpose – This research paper explores the transformative potential of Industry 5.0 for environmental, social and governance (ESG) factors within corporate settings. This study aims to elucidate the role of Industry 5.0 and its related technologies in influencing ESG factors, explore potential risks linked to ESG and present strategies formitigation through Industry 5.0.

Design/methodology/approach – This paper is the literature review that introduces Industry 5.0 as a pivotal factor in implementing and mitigating ESG and its related risks. It outlines Industry 5.0's characteristics, driven by advanced technologies.

Findings – Literature reviews suggest that Industry 5.0 has the potential to significantly influence ESG factors within corporate settings. It can promote sustainability, enhance working conditions and offer operational advantages.

Practical implications – The practical implications of this research paper are twofold. First, it provides valuable insights to policymakers, organizations and regulatory bodies, guiding them in adapting their frameworks to embrace Industry 5.0. This adaptation is essential for achieving ESG goals and facilitating sustainable development. Second, it highlights the critical role of Industry 5.0 in mitigating ESG-related risks, offering a robust structure for sustainable development.

Originality/value – This research paper contributes to the existing body of knowledge by highlighting the transformative potential of Industry 5.0 in the context of ESG. It offers a comprehensive exploration of the historical evolution of corporate governance, the integration of sustainability and the growing focus on ESG. It also highlights the originality and value of Industry 5.0 as a critical mitigating factor for ESG-related risks, presenting a holistic approach to sustainable corporate practices.

Keywords: Risk, Sustainability, Corporate governance, Advanced technologies, Industry 5.0, Environment social and governance

Paper type Literature review

1. Introduction

Corporations are the juristic person (Samaradiwakera-Wijesundara, 2022; Singh and Turaga, 2024) which requires rules, regulations and codes of corporate governance (CG) to operate in any country and or jurisdiction. The concept of CG is relatively old; however, in the wake up early 1990s frauds, CG was identified as the missing link that allowed

fraudsters to conduct fraud. Lack of CG or immature CG ensures the laws suits, resignations, bankruptcies and sometimes ends up in winding up of the entire organization (Rehman and Hashim, 2021; Larcker and Tayan, 2020; Rehman, 2024).

In early 2000, almost all countries adopted the codes of CG (Hermes et al., 2007) ensuring the fair treatment of the minority shareholders and emphasizes much on the disclosure requirements related to executive compensations and related party transactions (Buchanan and Deakin, 2024). However, the financial downturn of 2008 which was a severe economic recession that began in the USA and spread to the rest of the world (Matsubayashi et al., 2020), obliged organizations to have sustainable CG.

Sustainability is defined by United Nations (UN) as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 2023). This notion was necessary as organizations were looking at short-term profitability instead of long-term goals. Such organizational practices attracted the concept that the CG framework should incorporate sustainability more deeply to ensure sustainability considerations (Commission, 2020; Rehman, 2021).

European Commission (EC) emphasizes on the principals of sustainable CG by encouraging organizations to aligning the long-term interests of stakeholders and society as a whole through a holistic approach, integrate stakeholder concerns and sustainability considerations into strategies, establishing legal clarity for addressing adverse impacts, developing CG structures, empowering directors to consider broader interests, adopting nonfinancial reporting guidelines and implementing a sustainable CG strategy through effective risk management and impact mitigation procedures (Commission, 2020).

In year 2015, the concept of sustainability is enhanced when UN introduced 17 Sustainability Development Goals (SDG). These goals can easily be correlated with the environment, social and governance (ESG) factors (Delgado-Ceballos et al., 2023) and obliges organizations to achieve ESG to achieve and maintain sustainability. It is worth noting that ESG requires innovation and technology to be supported, which can be provided by Industry 5.0.

ESG has earned significant attention, and financial institutions are increasingly emphasizing their support for organizations committed to ESG principles. ESG assets on a global scale are projected to surpass $53tn by 2025 (Clark and Dixon, 2024), constituting over a third of the

anticipated $140.5tn in total assets under management. The convergence of factors, including the pandemic and the green recovery initiatives in the USA, European Union and China, is poised to demonstrate how ESG criteria can be instrumental in evaluating emerging financial risks and leveraging capital markets (Diab and Adams., 2023). However, it also brings the potential risk of fraud and misappropriation of assets. ESG-related fraud risks encompass greenwashing, social injustice, nonperforming loans and governance-related fraudulent activities. Table 1 demonstrates the fraud related to ESG in recent corporate world:
Corporations often promote public initiatives to showcase their dedication to ESG causes. Nevertheless, many of these initiatives closely align with the company's established

Table 1 ESG-related frauds

Case	*Year*	*Description*	*Source*
Volkswagen emissions scandal	2015	Volkswagen was caught cheating on emissions tests for its diesel vehicles. The company admitted to installing software that allowed its vehicles to pass emissions tests in the lab while emitting significantly more pollutants on the road	Jung and Sharon (2019)
Wells Fargo fake accounts scandal	2016	Wells Fargo employees opened millions of unauthorized bank and credit card accounts for customers without their consent. This scandal raised concerns about the company's governance and social responsibility practices	Ragothman *et al.* (2022)
DWS greenwashing scandal	2022	DWS, the asset management arm of Deutsche Bank, was accused of greenwashing by the US Securities and Exchange Commission (SEC). The SEC alleged that DWS overstated the ESG credentials of its funds and misled investors about the extent to which the funds were invested in sustainable	Sipiczki (2022)

business model but these initiatives never demonstrate organizational willingness to invest in expensive projects to address ESG requirements (Larcker and Tayan, 2020). This poses a huge risk to stakeholders' needs and requires proper mitigation actions keeping in mind the short and long-term objectives of the organization. There could be many mitigating factors that can assist implementation of ESG in corporate world and one of the major mitigating tools is the implementation and adoption of Industry 5.0.

Industry 5.0 has the potential to make a positive impact on all aspects of ESG. By putting people at the center of the industrial process and using technology to improve working conditions, education and opportunities, Industry 5.0 can help to create a more sustainable and equitable society (Leng et al., 2022). Industry 5.0 is the next generation of industrialization, characterized by a focus on human-centricity, sustainability and resilience (Xu et al., 2021). Augmented reality (AR), artificial intelligence (AI), blockchain technology and big data are all key enabling technologies for Industry 5.0 (Xian et al., 2023).

Industry 5.0, though still in its early developmental stages (Leng et al., 2022), holds the

potential to reshape our approach to production and consumption. Used technologies are pivotal in facilitating this transformation, altering the way organizations proceed. The adoption of technologies in Industry 5.0 offers several advantages (Paschek et al., 2022), including heightened efficiency and productivity through task automation and streamlined processes. It also enhances quality and safety by identifying defects and reducing hazards, resulting in improved products and safer workplaces; furthermore, cost reduction can also be achieved through process optimization (Hermann, 2019; Chen, 2023). Industry 5.0 foster innovation by enabling the development of new products and services while enhancing existing ones (Chung et al., 2020). Industry 5.0 can contribute to an enriched customer experience by providing businesses with deeper insights into their customers, enabling more personalized and engaging interactions. Table 2 demonstrates how organizations are implementing Industry 5.0 in helping the society and their organization as well:

On the environmental front, Industry 5.0 can champion sustainability by leveraging advanced technologies and processes to optimize resource utilization, minimize waste and reduce its overall environmental footprint (Almusaed et al., 2023). With the human-centric approaches, Industry 5.0 enhances working conditions, job satisfaction and developmental opportunities (Doyle Kent and Kopacek, 2021), closely aligning with organizational environment of ESG criteria. Industry 5.0 reduces the risk of environmental noncompliance, regulatory fines and reputational damage associated with unsustainable practices (Asif et al., 2023). It reduces the risk of social unrest, labor disputes and negative public perception, which can harm a company's reputation and shareholder value (Orlova, 2021; Saniuk et al., 2022).

In addressing social ESG aspect, Industry 5.0 can aid in mitigating inequalities by not only creating new employment opportunities but also through diversity and inclusion efforts, identifying and rectifying biases in hiring and promotions (De Giovanni, 2023). It also

Table 2 Implementation of Industry 5.0 for better society

Company	*Use case*	*Impact*	*Source*
Volvo Trucks	Train drivers on new safety features	Improve driver safety and reduce accidents	Hermann (2019)
Siemens	Identify and address visibility to grid's status	Create weather and charging infrastructure in advance	Stein (2020)
Nike	Track the environmental impact of its supply chain	Make more sustainable choices	Chen (2023)
Nestlé	Improve the health and well-being of its customers	Create a healthier environment	Chung *et al.* (2020)

protects worker welfare by automating hazardous tasks, reducing workplace injuries and illnesses, thereby aligning with both social and governance aspects of ESG. Furthermore, Industry 5.0 empowers companies to engage with communities by applying their resources and expertise to tackle societal challenges like public health and education (Carayannis and Morawska-Jancelewicz, 2022). This comprehensive integration of Industry 5.0 into ESG factors offers a robust structure for sustainable development across all dimensions. Industry 5.0 also has the capacity to bolster governance practices (Elangovan, 2021). It supports transparent decision-making processes, fosters ethical leadership and enables data-driven governance (Maddikunta et al., 2021), thereby contributing to better CG that resonates with ESG objectives. Furthermore, it facilitates investment in skills and education, a critical aspect of ESG, by addressing the need for training and development programs to equip the workforce with the necessary skills for sustainability (Xu et al., 2021). Industry 5.0 reduces governance-related risks such as fraud, unethical behavior and regulatory noncompliance by identifying risk (Rupa et al., 2021), providing timely insights and predictive capabilities.

To the best of the knowledge of researchers, there is limited studies conducted on the topic of Industry 5.0 and its impact on ESG in terms of corporate settings. This paper aims to contribute to the existing body of knowledge by highlighting the potential of Industry 5.0, its related technologies and their impact on ESG factors. In addition, this paper will address potential risks associated with Industry 5.0 and discuss mitigation strategies. It is expected that this paper will benefit policymakers, organizations and regulatory bodies by assisting them in updating their codes, laws and organizational policies to accommodate the requirements of Industry 5.0 and the achievement of ESG goals.

The motivation for this research is driven by the urgent challenges faced by modern organizations in the areas of CG, sustainability and ESG compliance. With increasing instances of fraud, environmental degradation, social inequalities and regulatory noncompliance, there is a pressing need for innovative solutions that can drive meaningful change. Despite the adoption of CG codes and sustainability measures, gaps remain in understanding how emerging technologies like Industry 5.0 can reshape these practices for the better. This research seeks to address these critical gaps by focusing on the potential impact of Industry 5.0 technologies on ESG factors within corporate settings, an area that

has seen limited exploration in existing literature. By exploring into this unprecedented domain, the study aims to not only advance academic knowledge but also provide actionable insights for policymakers, organizations and regulatory bodies, guiding them in updating codes, laws and policies to align with ESG goals and promote sustainable practices.

Emphasizing the innovative aspect of Industry 5.0, this research aims to highlight practical implications and real-world applications that can drive positive change in CG and sustainability practices. By bridging the gap between theoretical understanding and practical implementation, the study intends to inspire a call to action, urging stakeholders to recognize the transformative potential of Industry 5.0 technologies. Through AI, blockchain, big data and other Industry 5.0 tools, organizations can enhance efficiency, transparency and risk management, ultimately fostering a more sustainable and equitable business environment. Emphasizing the innovative aspect of Industry 5.0, this research aims to highlight practical implications and real-world applications that can drive positive change in CG and sustainability practices. By identifying urgent issues and research gaps and providing a roadmap for harnessing Industry 5.0 innovation, this research aims to inspire long-term sustainability and success in the corporate world. Through AI, blockchain, big data and other Industry 5.0 tools, organizations can enhance efficiency, transparency and risk management, ultimately fostering a more sustainable and equitable business environment.

2. Literature review

This section will discuss CG, sustainability, ESG and how Industry 5.0 can impact the ESG in achieving sustainability. This section will also explore how Industry 5.0 is used as a pivotal factor in implementing and mitigating ESG-related risks.

2.1 Corporate governance

CG can be defined as a set of rules and regulations that are necessary for organizational survival. In the current business environment, codes of CG are made necessary by the regulatory authorities and involve six major constituents of CG, namely, board of directors (BOD), audit and risk committee (ARC), compensation and nomination committee (CNC), senior/executive management (SM), internal audit (IA) and external audit (EA). These

constituents are considered as the caretaker or protector of the governance of organizations.

Even with the introduction of CG codes, organizations use them as the compliance check box only and do not consider them as an effective tool which can enhance organizational sustainability. Several studies are available which define that CG codes are not enough for organizations to think sustainable solutions. Furthermore, due to the nonavailability of sustainability clauses within CG codes also creates potential for agency conflicts.

2.2 Sustainability

Sustainability is defined as the ability to preserve a state of well-being for an extended, possibly even an unlimited duration (Kuhlman and Farrington, 2010; Wynsberghe, 2021). Sustainability is required to be embedded into the organizational culture, their mission, vision and CG codes. In the current business environment, approximately 90% of the world economy is managed by corporations (Reaction, 2022; Bayraktar and Algan, 2019). Irrespective of government initiatives, unless organizations are compelled to integrate sustainability into their CG, such efforts would be futile. Sustainability can only become meaningful when organizations actively participate; otherwise, it remains an empty slogan. UN issued 17 goals for sustainable development. These goals are required to be embedded into the CG codes of countries and into the organizational policies (Rehman et al., 2023). Although the shift towards sustainability requires time; therefore, several countries have issued there long-term plan such as Oman Vision 2030 and Saudi Vision 2040 (Al Lawati, 2022; Amran et al., 2020). These visions are encouraging organizations to adopt sustainability initiatives, but not obliging them to follow. There are several challenges which are still not addressed (Filho et al., 2020); furthermore, there are no comprehensive tools available that can measure the sustainability of the organizations against their country's visions. There are metrics available which differ from one rating agency to another.

As Industry 5.0 emerges, there is a growing focus on sustainability efforts, particularly in the context of sustainable development goals (Singh, 2022). Industry 5.0 offers a promising pathway to enhance sustainability across various sectors including education (Jabeen, 2022). It promotes the integration of circular economy principles, emphasizing resource efficiency and waste reduction (Dlamini et al., 2023). By decentralizing manufacturing

processes and enabling local production, it reduces the carbon footprint associated with long-distance transportation and increases/enhances workforce.

Industry 5.0's which is enhanced form of digitalization, emphasizes on customization and efficiency leads to the creation of more sustainable products with longer lifespans, contributing to resource conservation (Broccardo et al., 2023). It also focuses on energy efficiency through smart manufacturing and predictive maintenance helps lower energy consumption and costs (Singh, 2022).

2.3 Sustainable corporate governance

In the current business environment, sustainability is one of the biggest global challenges. Climate change, inequality and other major social and environmental problems are pressing issues that require urgent action. Governments, regulators and international organizations are taking steps to address these challenges. They are implementing extensive measures to reshape organizational lifestyles, occupations and pursuit of well-being, all with the goal of ensuring long-term viability. Notable international initiatives like the European Green Deal, the Inflation Reduction Act and the SDGs are playing a key role in driving this transformation (Hobbs, 2023).

Organizations play a crucial role in developing sustainable economies while considering the environmental concerns coupled with social well-being. Sustainability into CG is considered as the organizational capability to impact environment, social and economic development through their CG practices (Krechovsk_a and Proch_azkov_a, 2014). This means considering how their business decisions impact their employees, customers, the community and society as whole. To achieve true sustainability, organizations are required to balance all three pillars such as organizations can invest in renewable energy to reduce their environmental impact, while also providing fair wages and benefits to their employees. CG can help companies implement a comprehensive sustainability strategy. This includes setting goals, tracking progress and making sure that all stakeholders of the organization are aligned with the sustainability vision (Safdie, 2023).

2.4 Environmental, social and governance

ESG sustainability is a framework that can be used by businesses and investors to evaluate and measure the impact of a company's operations on the environment, society and its governance practices (Hill, 2020). ESG criteria are also used to assess the ethical and

sustainability performance of a company and its potential for long-term financial success (Ng et al., 2020). The ESG framework can be used by investors to make socially responsible investment decisions. Companies that excel in ESG criteria are seen as more sustainable and resilient in the long term, which can attract responsible investors and customers (Park and Jang, 2021). In addition, it is often used as a risk management tool as it helps identify potential issues that could impact a company's performance, reputation or even legal standing. Buallay (2019) reported that many companies are now voluntarily reporting their ESG efforts in their annual reports and other disclosures to show their commitment to sustainability and corporate responsibility.

The Environmental (E) component includes climate change, resource management, biodiversity and conservation and pollution and waste. The climate change element can include a company's efforts to reduce its carbon footprint, transition to renewable energy sources and adapt to the challenges posed by climate change (Ol_ah et al., 2020). Likewise, resource management focuses on the responsible use of natural resources, such as water, land and raw materials, to minimize waste and environmental impact (Irfan et al., 2022). In relation to biodiversity and conservation, the companies are evaluated on their efforts to protect and promote biodiversity, avoid habitat destruction and support conservation initiatives (Bohnett et al., 2022). Finally, the pollution and waste element consider a company's measures to reduce pollution, minimize waste and responsibly manage hazardous materials (Oloruntobi et al., 2023).

The Social (S) elements of sustainability include several dimensions including diversity and inclusion, labor practices, community engagement and human rights (Luna-Nemecio et al., 2020). Under the diversity and inclusion subelement, the companies are evaluated on their policies and practices related to diversity and inclusion, such as gender, racial and ethnic diversity within the workforce and leadership (Jonsen et al., 2021). The labor practices involve fair and ethical treatment of employees, including issues like fair wages, working conditions and employee benefits (Aggarwal and Singh, 2019). Under the community engagement companies assess the involvement in the communities where it operates, such as philanthropic efforts and social initiatives (Stocker et al., 2020). According to Rajesh (2020), the human rights element, companies are expected to respect and uphold human rights both within their own operations and across their supply chains.

The Governance (G) element of sustainability includes subdimensions such as CG, ethical business practices, audit and accounting and stakeholder engagement (Hamad et al., 2020). Under the CG element, the company's board structure, executive compensation, transparency and shareholder rights are evaluated to ensure proper oversight and accountability (Naciti et al., 2021). Ethical business practices encompass anti-corruption measures, code of conduct and adherence to ethical business standards (Waheed and Zhang, 2022). Audit and accounting element ensures that financial statements are accurate and transparent, and that there is appropriate oversight in place to prevent fraud (Dhar et al., 2022). The stakeholder engagement involves communication with and responsiveness to various stakeholders, including employees, customers, shareholders and the broader community (Stocker et al., 2020).

Technology plays a crucial role in advancing ESG sustainability efforts by providing tools, data and solutions that enhance the measurement, reporting and management of ESG-related factors (Saxena et al., 2022). The technology efforts in EGS start from data collection and analysis, supporting all other stages including emissions reduction and resource efficiency, reporting and disclosure, stakeholder engagement, risk management and compliance, investor relations, e-learning and training and crowdsourcing and collaboration (Alkaraan et al., 2022). A detailed discussion on these dimensions is provided in Section 2.5.

2.5 Industry 5.0

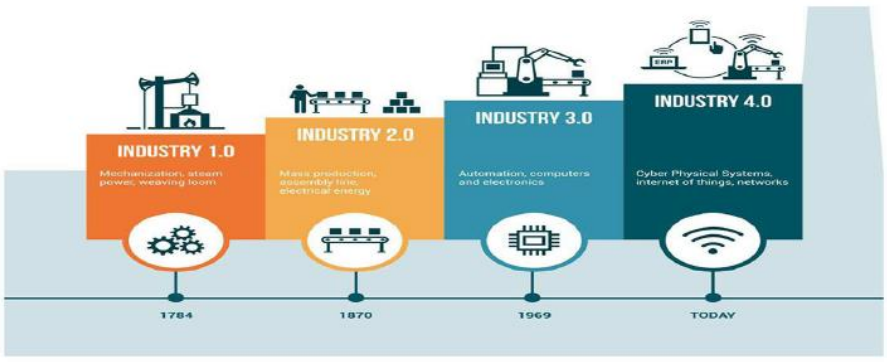
The industrial revolution was a period of profound economic, technological and social change that began in Britain in the late 18th century and eventually spread to other parts of the world. It marked a transition from agrarian and handcraft-based economies to industrial and mechanized ones (De Vries). The industrial revolution had significant and far-reaching effects on society and the global economy. For instance, as industries grew, people moved from rural areas to cities in search of jobs, leading to rapid urbanization. Likewise, industrialization led to increased economic output, improved living standards and a rise in consumer goods. Similarly, it transformed social structures and family dynamics as the workplace and the home became more separated. Labor movements and unions also emerged in response to poor working conditions (Stearns, 2020). On the contrary, the industrial revolution had a profound impact on the environment through pollution, deforestation and the depletion of natural resources (Williams, 2005). The shift from agrarian

economies to industrial ones played a role in shaping political ideologies and systems. The industrial revolution was a period of both immense progress and significant challenges. It laid the foundation for the modern industrialized world and set the stage for subsequent technological and economic developments.

The first industrial revolution was from 1760 to 1840 as shown in Figure 1 (Groumpos, 2021). The mechanization of agriculture, textile manufacturing and mining significantly increased productivity. Inventions like the spinning jenny and the power loom revolutionized the textile industry. The invention of the steam engine by James Watt in the 1760s revolutionized transportation and industrial production (Van der Kooij, 2015). The factory system emerged, concentrating production in large, centralized facilities with specialized machinery and a labor force.

The second industrial revolution is considered from mid-19th to early 20th century (Mokyr and Strotz, 1998). This phase was characterized by further technological innovation, including the development of the telegraph, telephone and electric power. The steel

Figure 1 The industrial revolutions (1–4)



Source: Groumpos (2021)

industry, led by innovations such as the Bessemer process, and the chemical industry grew rapidly. The expansion of railroads facilitated the movement of people and goods over long distances. The development of assembly lines and interchangeable parts in manufacturing, often associated with Henry Ford, made mass production of goods more efficient (Agarwal and Agarwal, 2017).

The third industrial revolution started in the late 20th century (Janicke and Jacob, 2013). This phase was marked by the emergence of digital technology, including computers, the internet

and information technology. The integration of computers and robotics into manufacturing processes transformed industries and increased productivity. Advances in transportation and communication led to increased global trade and the interconnectedness of economies (Taalbi, 2019).

The fourth industrial revolution, often referred to as Industry 4.0, is a term that describes the ongoing transformation of traditional manufacturing and industrial processes with modern digital technology (Skilton and Hovsepian, 2018). It builds upon the progress made during the third industrial revolution, which introduced computerization and automation to industries. The fourth industrial revolution represents a fusion of advances in various fields, for example AI and machine learning are being used to analyze large data sets, make predictions and automate decision-making processes in industries such as health care, finance and manufacturing (French et al., 2021).

The proliferation of Internet of things (IoT) devices, which are interconnected and can collect and transmit data, has enabled more efficient and data-driven processes. For example, smart homes, smart factories and smart cities rely on IoT (Ross and Maynard, 2021). Distributed ledger technology, like blockchain, is used to enhance security and transparency in financial transactions, supply chains and various other applications (French et al., 2021). The ability to collect, store and analyze vast amounts of data has led to datadriven decision-making in many industries. This is crucial for understanding trends, customer behavior and optimizing processes (Choi et al., 2019). Technology such as 3D printing allows for the rapid and cost-effective production of complex components and prototypes. It is used in various industries, from aerospace to health care (Umar, 2020).

The use of advanced robots and drones for tasks ranging from manufacturing and agriculture to health care and logistics are becoming increasingly in the fourth industrial revolution (Karabegovi_c, 2018). Similarly, AR and virtual reality are used to enhance training, maintenance and design processes in numerous industries (Huang et al., 2018). The fourth industrial revolution has brought advances in biotechnology that have led to breakthroughs in health care, agriculture and environmental conservation (Odhiambo, 2019). The fourth industrial revolution also emphasizes the importance of sustainable practices and technologies to address environmental challenges (He and Ni, 2022). With the increasing connectivity of devices and systems in the fourth industrial

revolution, the need for robust cybersecurity measures has grown significantly (Lee et al., 2021).

The concept of a “fifth industrial revolution” had not gained widespread recognition or definition in the same way that the fourth industrial revolution (Industry 4.0) had. However, discussions about future industrial revolutions were beginning to emerge, and there were some trends and areas of technological development that could potentially shape a “fifth industrial revolution” in the coming years (Mourtzis, 2021). Some potential elements and trends that might contribute to a fifth industrial revolution include for example it is expected that continued advancements in AI, including the development of more sophisticated and autonomous AI systems, could lead to a significant transformation in how industries operate (Pathak et al., 2019). The development of practical quantum computers could revolutionize computing power, enabling the processing of vast amounts of data and solving complex problems that are currently intractable for classical computers (Burkacky et al., 2020). Likewise, further progress in nanotechnology could lead to the creation of new materials, advanced drug delivery systems and innovations in manufacturing and electronics (Buzdugan et al., 2022). Ongoing breakthroughs in biotechnology, gene editing and personalized medicine may significantly impact health care, agriculture and beyond.

The transition to renewable energy sources and the development of more efficient and sustainable technologies will continue to be a major driver of change. The expansion of human activities in space, including lunar and Mars missions and the growth of the space industry, could bring about new economic and technological paradigms (Iliopoulos and Esteban, 2020). The development of novel materials with unique properties could lead to innovations in various industries, including electronics, construction and transportation. Expanding global connectivity through 5G and beyond, as well as satellite internet, could lead to further changes in communication, data transfer and remote work capabilities. As technology continues to advance, the need for robust cybersecurity and data privacy measures will remain critical (Onik et al., 2019). Advancements in technologies like brain–computer interfaces and wearable tech could enhance human capabilities and change the way we work and interact with technology (Harborth and Ku¨mpers, 2022).

2.6 Industry 5.0 and environmental, social and governance

While Industry 5.0 and ESG are two distinct concepts, but they are interconnected in the

context of modern industrial practices and sustainability efforts (Asif et al., 2023). As discussed earlier, the Industry 5.0 is an emerging concept that builds upon the foundation of the fourth industrial revolution (Industry 4.0). It focuses on the importance of human–machine collaboration in manufacturing and industrial processes. While Industry 4.0 emphasizes automation and the use of technologies like AI, IoT and robotics to optimize operations, Industry 5.0 brings a human touch back into the equation. It envisions a future where humans and machines work together more closely, with advanced technologies enhancing human capabilities rather than replacing human workers.

In Industry 5.0, there is a shift toward more personalized and customized production, where human workers, supported by technology, play a critical role in decision-making, creativity and problem-solving. This approach is expected to lead to more sustainable and responsible manufacturing practices. ESG refers to a set of criteria that investors, businesses and organizations use to assess a company's impact and sustainability performance. Industry 5.0 can contribute to ESG goals in various ways for example, in term of environmental sustainability, the Industry 5.0, with its focus on efficiency and reduced waste, can help companies improve their environmental performance by optimizing resource use and reducing energy consumption (Ghobakhloo et al., 2022). In relation to social responsibility, though emphasizing the human-machine collaboration, Industry 5.0 can promote better working conditions and safety for employees.

Industry 5.0 also fosters skill development and employee empowerment (Banholzer, 2022). The integration of Industry 5.0 technologies can improve data transparency, governance and compliance. It can also support ethical business practices and responsible leadership (Xu et al., 2021). Finally, Industry 5.0 through customization and sustainability can play a better role as Industry 5.0's approach to more personalized production can reduce overproduction and waste, aligning with environmental and social responsibility goals (Aheleroff et al., 2022). It can be argued that Industry 5.0, with its emphasis on human–machine collaboration and sustainable manufacturing, aligns well with ESG principles. Companies that adopt Industry 5.0 practices can improve their ESG performance by fostering environmental stewardship, social responsibility and good governance, ultimately benefiting both their stakeholders and the planet.

2.7 Risk related with environmental, social and governance

Within the domain of ESG considerations, a host of risks emerge, many of which overlap with the realm of fraudulent activities. Fraud can be defined as a breach of trust (Othman and Ameer, 2022), where organizations, under the guise of promoting environmentally and socially responsible practices, gain the trust of consumers to market their products, while the actual reality may starkly contrast these claims. Similar notion can go for the products which are backed by shady governance practices such as 1 MDB fraud, where whole nation suffered because of poor governance and lack of internal controls (Jones, 2020). ESG risks are defined below:

2.7.1 Greenwashing risk. Greenwashing can be labelled as the overall risk for ESG.

Greenwashing can be defined as the difference between what an organization says it does and what actually organization is doing. Greenwashing has become more common in recent years, and it is now a widespread problem that involves organizations, governments, political figures, research institutions, international organizations, nongovernmental organizations and social and environmental movements (Ruiz-Blanco et al., 2022). Greenwashing is a serious risk as it can mislead consumers and undermine efforts to address climate change, social or governance impact. When consumers believe that a product is environmentally friendly or backed by good governance, they may be more likely to buy it, even if it is not actually good for the environment or contains fraudulent intentions. This can lead to increased sales for companies that are greenwashing, which can give them an unfair advantage over companies that are committed to sustainable practices. It is important to note that there is no universally accepted definition of greenwashing (Seele and Gatti, 2017). This means that it can be difficult to identify and prove cases of greenwashing. However, there are several red flags that can indicate that a company may be greenwashing which can easily be implemented and activated with Industry 5.0 measures.

In year 2021, a series of advertisements by HSBC emerged at bus stops across the UK as part of a promotional campaign centered on the slogan “Climate change doesn’t adhere to borders.” These advertisements featured visual imagery of trees and ocean waves, accompanied by statements highlighting the bank’s purported commitment to financing the

transition toward a net-zero carbon footprint and its intention to facilitate the planting of 2 million trees (Rudgard, 2023). However, it was later identified that HSBC had sent $130bn of financing to fossil fuel companies in recent years (Force, 2021).

It is worth noting that a substantial segment of consumers increasingly gravitates toward products boasting stronger environmental and social credentials, even if they entail a higher cost. This inclination was evident in a recent survey conducted in the USA, wherein 68% of respondents expressed their willingness to select products with enhanced environmental attributes (Rudgard, 2023; Migliore et al., 2018), notwithstanding the potential price premium associated with such selections (Nguyen et al., 2021). This phenomenon signifies a notable marketing potential for businesses. However, it simultaneously poses a formidable challenge for regulatory authorities, which frequently lack comprehensive mechanisms to combat incomplete or deceptive environmental assertions effectively.

There is compelling evidence to suggest a noticeable uptick in the prevalence of environmentally and socially oriented marketing claims. In accordance with the report from the UK-based consumer research agency Mintel disclosed that the percentage of beauty and hygiene products featuring environmental or ethical claims surged from 27% in 2015 to 46% in 2019 (Dover, 2022). In a separate study conducted by Australia's Consumer Policy Research Centre, it was revealed that consumers in Australia are potentially exposed to an astonishing 122 instances of green claims within a 24-h timeframe (Burry, 2022).

This escalating proliferation of green marketing claims has had discernible consequences, as consumer sentiment has shown signs of fatigue and disenchantment. A recent survey in the UK, conducted by KPMG consultancy, unveiled that one-third of respondents expressed skepticism regarding green labels and sustainability assertions, with over half indicating their willingness to cease purchasing from companies found guilty of engaging in greenwashing practices (Andrews, 2023).

2.7.2 Environment risk.

Environmental or climate-related risks have the potential to embroil organizations in a range of detrimental consequences, including the erosion of public trust, harm to their reputation, financial setbacks and adverse impacts on society as a whole. Numerous instances exist where organizations have influenced the climate, resulting in detrimental repercussions for society and substantial financial losses for the companies

involved. Table 3 demonstrates the few of the prominent fraud related to this risk:
Table 3 highlights the spectrum of environmental frauds committed by prominent companies. These cases span across different years and encompass a wide range of fraudulent activities, including emissions scandals, climate denial, rainforest destruction, gas flaring, environmental damage and catastrophic disasters. Notably, diverse methods were used by which these fraudulent activities were uncovered; however, there is no standard mechanism available that can prevent such risk from occurring or detect when such event occurred.

2.7.3 Social risk.

Social risk, an integral aspect of ESG and encompasses a wide spectrum of factors with the potential to affect businesses. One critical dimension of social risk involves labor practices, where issues like unfair wages, inadequate working conditions, occupational safety concerns, worker rights violations and labor disputes can emerge. Inadequate diversity and inclusion efforts can also pose a risk, hindering talent attraction and retention. Violations of human rights, either within a company or its supply chain, represent another facet of social risk, including matters like child labor and forced labor. Organizations may face reputational damage and legal consequences if they fail to uphold ethical business practices, such as engaging in corruption or bribery. Furthermore,

Table 3 Environment fraud cases

Company	*Year*	*Climate fraud*	*Discovery of fraud by*	*Fine/Penalty*	*Source*
Volkswagen	2015	Emissions scandal	Whistleblower	€30bn	Davis (2019)
ExxonMobil	Ongoing	Climate denial	Internal documents	$236m	Henricksen (2019)
Chevron	Ongoing	Rainforest destruction	Lawsuit	$9.5bn	Guzman-Diaz (2020)
Shell	Ongoing	Gas flaring	Environmental groups	$2bn	Tattersall (2010)
BP	2010	Deepwater horizon disaster	Investigation	$18.7bn	Robertson *et al.* (2015)
Formosa Plastics	2019	Environmental damage	Lawsuit	$50m	Smith (2019)

mishandling consumer data, disregarding data privacy regulations, or failing to engage with local communities responsibly can lead to social risk. Table 4 demonstrates the social frauds conducted by the organizations which end up in reputational damage and financial impact. Table 4 emphasizes that organizations which are not socially active can suffer losses. All these organizations have been operating for decades and enjoy a good reputation. However, there were no preventive measures conducted which resulted in reputational damage coupled with financial penalties. In the case of Nike, the organization took steps to address the issue, such as conducting audits of its suppliers and terminating contracts with

suppliers that violate its labor standards. Effective management of these social risks is essential for businesses aiming to build trust with stakeholders, protect their reputation and uphold responsible corporate practices within the realm of ESG.

2.7.4 Governance risk.

The governance aspect of ESG is a multifaceted area that underpins organizational ethical conduct and relationship with stakeholders. It encompasses several critical elements, including codes of conduct, accountability, transparency, executive compensation, board composition, anticorruption measures, stakeholder engagement and shareholder rights (Rehman et al., 2023). Governance is key for achievement of environment and social factors. Poor and or weak governance provides motivation and rationale for people to conduct fraud. Table 5 demonstrates the fraud which occurred due to poor governance: Instances mentioned in Table 5 underscore the critical importance of robust governance, transparency and effective oversight mechanisms to prevent and detect fraud within corporate structures. They serve as stark reminders of the potential risks and consequences associated with fraudulent activities in the corporate world, reinforcing the need for vigilant governance practices and ethical standards to maintain the integrity of financial markets and protect stakeholders.

2.8 Industry 5.0 and risk mitigation

Industry 5.0, with its advanced technologies and emphasis on innovation, can play a pivotal role in mitigating the risks associated with ESG factors. Industry 5.0 can address the specific risks as follows:

Table 4 Social frauds

Company	*Year*	*Social risk or fraud*	*Discovery*	*Fine/penalty*	*Source*
Wells Fargo	2022	Fake accounts scandal	Whistle blower	$3bn	Shichor and Heeren (2021)
Uber	2022	Sexual harassment and discrimination	Internal investigation and lawsuits	$10m	Howcroft and Taylor (2023)
Amazon	2021	Warehouse safety violations	Whistleblower and media reports	$61m	Gordon (2021)
Nike	2021	Forced labor in the supply chain	Whistleblower and media reports	None	Doorey (2021)
Walmart	2019	Bribery and corruption in the supply chain	Internal investigation and media reports	$282m	Bose (2019)

Table 5 Governance frauds

Company	*Year*	*How it was detected*	*Amount of fraud*	*Source*
Wirecard	2020	Whistleblower and audit	€1.9bn	Miller and Mintz (2023)
Theranos	2018	Whistleblower and media reports	$945m	Adorjan and Colaguori (2023)
Olympus	2011	Internal investigation	¥1.7tn	Renou and Burger-Helmchen (2023)

2.8.1 Greenwashing risk mitigation.

Industry 5.0 is a new industrial revolution that is driven by advanced technologies such as AI, big data and the IoT (Zdemir and Hekim, 2018). Industry 5.0 has the potential to revolutionize the way that sustainability claims are verified. By leveraging advanced data analytics, AI and blockchain technology (Akundi et al., 2022), Industry 5.0 can make it more difficult for organizations to engage in greenwashing and can help consumers to make more informed choices.

One of the key features of Industry 5.0 is its ability to collect and analyze vast amounts of data from a variety of sources (Chander et al., 2022). This data can be used to assess the authenticity of sustainability claims in a number of ways, such as data analytics and AI can be used to identify and flag inconsistencies in company reports and disclosures, track the performance of companies over time to see if they are meeting their sustainability goals and compare the performance of different companies in the same industry to see who is leading the way on sustainability (Rupp and Hillekamp, 2021; Yin and Yu, 2022).

Blockchain technology can also be used to verify sustainability claims (Balzarova, 2021). Blockchain is a distributed ledger technology that can be used to create transparent and immutable records of transactions. Blockchain can be used to track the movement of products through a supply chain (Azzi et al., 2019), from raw materials to finished product. This information can be used to verify that products are being produced sustainably and that they meet the company's sustainability claims.

2.8.2 Environment risk mitigation.

Industry 5.0 represents a significant shift in industrial practices, with a strong emphasis on sustainability (Ivanov, 2023). This new era in industry is characterized by the integration of advanced technologies and practices aimed at reducing environmental impact and promoting sustainable development (Paschek et al.,2022; Nicolae et al., 2023).

One key aspect of Industry 5.0 is the adoption of smart manufacturing and supply chain management systems (Azzi et al., 2019). These systems leverage data from various sources, including IoT sensors (Zdemir and Hekim, 2018), to optimize the utilization of resources. They can help organizations to streamline their operations, minimize waste and reduce their carbon footprints. Industry 5.0 can assist organizations by closely monitoring energy consumption (Zdemir and Hekim, 2018), identify and rectify areas of inefficiency, leading to substantial energy savings and reduced environmental impact (Turner et al., 2022).

IoT sensors and AI-driven analytics play a pivotal role in Industry 5.0. They enable companies to proactively detect and respond to environmental hazards (Caiazzo et al., 2023). Industry 5.0 can continuously monitor equipment and processes for anomalies (Maddikunta et al., 2021), such as leaks or emissions and at the same time AI algorithms can trigger immediate alerts or even take autonomous actions to mitigate the risk (Falco et al., 2021). This not only reduces the chances of environmental disasters but also helps in

compliance with stringent environmental regulations.

Advanced modeling and simulation tools are another crucial component of Industry 5.0 (Gaiardelli et al., 2021). These tools enable companies to simulate various scenarios related to climate and environmental conditions. By doing so, businesses can better prepare for climate-related risks (Ng et al., 2021; Balde et al., 2023), such as extreme weather events or supply chain disruptions. This proactive approach allows organizations to develop strategies to address and adapt to these challenges effectively, minimizing their impact on the environment and business continuity.

2.8.3 Social risk mitigation.

Industry 5.0 holds the potential to mitigate social risks associated with the social aspect of ESG (Asif et al., 2023) through a holistic and responsible approach to industrial practices. It promotes workplace safety and well-being by leveraging advanced technologies like AI and automation, reducing the likelihood of accidents and prioritizing employee health (Cebulla et al., 2023). The integration of Industry 5.0 also facilitates workforce upskilling and training, helping employees adapt to evolving

roles and fostering a culture of lifelong learning (Hoitan, 2023). Moreover, this industrial paradigm promotes diversity and inclusion by using AI in recruitment to minimize biases, resulting in a more representative and equitable workforce.

Industry 5.0 encourages community engagement (Carayannis and Morawska-Jancelewicz, 2022), enabling organizations to work closely with local communities to address concerns and build trust. Supply chain transparency is enhanced, allowing companies to ensure ethical and sustainable sourcing practices, reducing social risks. Furthermore, the customization capabilities of Industry 5.0 lead to more accessible and inclusive products (Turner et al., 2022), catering to diverse customer needs, including those with disabilities. Industry 5.0 prioritizes social responsibility (Sindhwani et al., 2022), contributing to a more sustainable and inclusive future while reducing associated risks.

2.8.4 Governance risk mitigation.

Industry 5.0 offers a controlling framework for mitigating

governance risks within the context of ESG principles (Asif et al., 2023). Industry 5.0 promotes transparency and ethical conduct throughout various aspects of business operations (Longo et al., 2020). The data-driven nature of Industry 5.0 enables robust data integrity and transparency, minimizing opportunities for fraudulent or unethical activities (Guruswamy et al., 2022; Rupa et al., 2021). Technologies such as blockchain create

immutable records, increasing transparency in supply chains and financial transactions and making it more challenging for companies to engage in questionable practices (Dai and Vasarhelyi, 2017).

Industry 5.0 ensures compliance with complex and evolving regulations (Ghobakhloo et al., 2022). Smart contracts and automated systems can be programmed to enforce legal and ethical standards, reducing the risk of noncompliance, regulatory fines or legal disputes. Furthermore, it enhances board accountability by providing real-time insights and reporting tools (Rehman, 2023), which support better decision-making and oversight, reducing governance-related risks arising from a lack of accountability at the board level (Moats et al., 2022).

Cybersecurity is another area where Industry 5.0 excels (Rajabion, 2023), aiding in the protection of sensitive data and compliance with data security and privacy regulations. It also addresses ethical concerns in AI and decision-making, offering guidelines to prevent harmful or discriminatory use of AI. Enhanced stakeholder engagement and improved environmental impact reporting ensure better alignment with stakeholder expectations and reduce risks associated with governance. Industry 5.0 promotes transparent, ethical and accountable governance practices (Ghobakhloo et al., 2022), aligning businesses more closely with the governance aspect of ESG and thereby reducing associated risks.

2.8.5 Sustainable development goals implementation risk mitigation.

Industry 5.0 promotes precision, coordination and transparency (Ghobakhloo et al., 2022). It ensures that SDGs have clear, measurable objectives (mitigating vague goals), fosters collaboration among stakeholders (addressing collective action issues), identifies trade-offs and synergies through advanced analytics and enhances accountability through technologies like blockchain and real-time data tracking (Rajabion, 2023; Moats et al., 2022).

Industry 5.0 drives efficiency and innovation to reduce costs (alleviating financial constraints), offers online training and tools for capacity building, including virtual and augmented reality options (addressing capacity issues), encourages the adoption of advanced technologies and infrastructure (tackling technology challenges) and fosters a culture of adaptability and innovation, respecting local customs and traditions by addressing cultural barriers (Elangovan, 2021; Aslam et al., 2020).

3. Conclusion

This research paper has highlighted the transformative potential of Industry 5.0 within the

realm of ESG factors in corporate settings. The findings underscore the profound impact Industry 5.0 can have on sustainability, working conditions and overall corporate performance. However, it is essential to recognize that the journey towards ESG excellence is not without its challenges and risks. ESG-related fraud, greenwashing, social injustice and noncompliance issues continue to plague the corporate world, demanding a proactive approach to mitigation.

The practical implications of this research are clear. Policymakers, organizations and regulatory bodies should take heed of the insights presented in this paper and adapt their frameworks to embrace Industry 5.0. This adaptation is not just a strategic advantage but an imperative step in achieving ESG goals and fostering sustainable development. Industry 5.0 emerges as a potent mitigating force against ESG-related risks. It empowers organizations to not only enhance their performance but also safeguard against fraudulent practices, unethical behavior and regulatory noncompliance.

In a world where ESG considerations are gaining prominence, Industry 5.0 proves to be a beacon of hope for risk mitigation. It aligns with the United Nations' sustainability goals, emphasizes the long- term interests of stakeholders and society and empowers organizations to make a tangible impact on the environment, society and governance. By leveraging Industry 5.0, companies can not only bolster their own performance but also address and mitigate ESG-related risks effectively.

As this research paper bridges a notable gap in the existing body of knowledge regarding Industry 5.0 and ESG factors, it lays the foundation for further exploration and implementation of these ideas in corporate practices. It is our hope that this paper serves as a catalyst for positive change, encouraging organizations to embrace Industry 5.0 and integrate ESG principles into their operations, thereby fostering a more sustainable, responsible and risk-resilient corporate landscape.

This research paper has explored the synergies between Industry 5.0 and ESG factors, highlighting its transformative potential and practical implications for corporate sustainability. Industry 5.0 represents a paradigm shift in industrial practices, emphasizing human–machine collaboration, technological advancements and a holistic approach to addressing ESG challenges.

The literature review has highlighted how Industry 5.0 can mitigate various risks associated

with ESG factors. From addressing greenwashing and environmental risks to enhancing social responsibility and governance practices, Industry 5.0 offers a comprehensive framework for organizations to navigate the complexities of modern business landscapes.

The practical implications arising from this research are substantial and profound. Organizations, regulatory bodies and policymakers should leverage the insights from this study to adapt frameworks and regulations that align with Industry 5.0 principles. This study can be converted into empirical study where hypothesis can be developed, and variables can be defined in three main categories. Independent variables can include the adoption of Industry 5.0 technologies and sustainability initiatives, reflecting the integration of advanced technologies and sustainable practices within organizations. Dependent variables could focus on environmental performance, social impact and governance effectiveness, measuring aspects like carbon footprint reduction, social responsibility practices and regulatory compliance. Mediating and moderating variables can be organizational culture, industry sector and technological capabilities. These potential variables can collectively form the framework for analyzing the impact of Industry 5.0 on ESG performance metrics.

The integration of Industry 5.0 with ESG principles represents a crucial step toward building resilient, responsible and future-ready organizations. By embracing Industry 5.0 technologies and methodologies, companies can not only mitigate ESG-related risks but also create value for stakeholders and contribute positively to global sustainability goals.

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