Corporate governance determinants of sustainable manufacturing practice: the case of zero-defect manufacturing in multinational corporations

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Abstract

Purpose: This study investigates the corporate governance determinants of sustainable manufacturing practice using Zero-Defect Manufacturing (ZDM) from the stakeholder theory and legitimacy theory perspectives.

Design/methodology: Using a panel research design, the study analyses empirical data from Global 500 companies covering a 15-year period.

Findings: The results show that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing are positively associated with ZDM Practice, whilst Chief Executive Officer (CEO) Duality of Power has a negative impact. In the millennium development goals (MGDs) period, the foremost drivers of ZDM Practice are Board Independence, Board Gender Diversity, and Board Skills on Sustainable Manufacturing, whilst this shifted to Board Independence and Board Gender Diversity in the sustainable development goals (SDGs) period.

Originality/value: The study provides empirical evidence that organisations seeking to improve sustainable manufacturing practice may consider strengthening their corporate governance structures to demonstrate responsible manufacturing in line with stakeholders' expectations and to preserve corporate legitimacy. The results are robust to alternative proxies, potential endogeneity concerns, and sample selection bias.

Keywords: corporate governance; legitimacy theory; SDGs; sustainable manufacturing practice; zero-defect manufacturing

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1. Introduction

Globalisation is challenging manufacturing organisations to embrace production innovations to improve product and process quality in alignment with the tenets of sustainable manufacturing (Haridy et al., 2023; Donkor et al., 2024). A viable strategy that manufacturing organisations can implement to achieve process improvement and product innovation is sustainable manufacturing using zero-defect manufacturing (ZDM). ZDM refers to avoiding failures and imperfection in the production process for the purpose of obtaining the output quality possible (Fayyaz et al., 2024). Quality management strategies such as quality assurance, quality improvement, and quality inspection, amongst others, are, therefore, associated with ZDM, and are critical to achieving zero defects in the production process (Catenazzo & Paulssen, 2020). ZDM combines all the best features of traditional quality management methods but also incorporates all the new digital technologies that industry 4.0 and industry 5.0 can offer. ZDM has tremendous benefits to customers, organisations, and society such as promoting inclusive and sustainable industrialisation, increasing resource-use efficiency, and promoting greater adoption of clean and environmentally sound technologies and industrial processes (Khakpour et al., 2024; Psarommatis et al., 2024). Sustainable manufacturing using ZDM resonates with the United Nations (UN) sustainable development goals (SDGs), especially SDGs 9, 12, and 13, respectively. Therefore, embracing ZDM is essential for any forward-looking manufacturing organisation, as this can be one of the strategies to implement to achieve corporate sustainability target.

One of the major mechanisms for organisation self-regulation which enables corporate entities to engage in voluntary or discretionary sustainability practice, such as sustainable manufacturing/ ZDM, is corporate governance (Adel et al., 2019; Zhang et al., 2021; Al-Shaer et al., 2024). Corporate governance (CG) refers to the system by which companies are directed and controlled to ensure the achievement of set objectives (Erin et al., 2021; El Saleh & Jurdi, 2023). Within the context of the current study, CG structures are mechanisms which ensure that the activities of a company's management and the decisions of the board of directors lead to sustainable manufacturing practice such as ZDM.

Whilst it has been widely acknowledged that CG is critical for achieving sustainable manufacturing practice (Alfi et al., 2024; Mora et al., 2024), the review of literature on the nexus between CG structure and sustainable manufacturing practice reveals some gaps which the current study aims to address. First, literature is replete with studies on the impact of CG

on various sustainable manufacturing issues such as circular economy, carbon emissions, green innovation, and waste reduction, among others (e.g., Al-Shaer et al., 2024; Ben-Amar et al., 2017; Konadu et al., 2021; Oyewo et al., 2024; Tingbani et al., 2020). However, little is known on the extent to which CG structure affects sustainable manufacturing using ZDM. The relevance of CG to the ZDM discourse stems from the consideration that organisational commitment to improving product quality through defect manufacturing initiatives is predominantly voluntary and not mandatory for many multinational corporations (MNCs). Engaging in responsible manufacturing, ensuring customer health and safety by reducing defective products, and implementing various sustainable manufacturing initiatives require strong ethical consideration on the part of MNCs, particularly given that MNCs operate in many jurisdictions in developing countries where the environmental laws are not robust or rigorous enough to protect members of the public. Given that decision making on ethical issues such as ZDM rests firmly with the board of directors, it is important to investigate the extent to which CG structure is influencing sustainable manufacturing practice such as ZDM.

Second, sustainable manufacturing is mainstream among the priority areas set out in the sustainable development agenda 2030 (i.e., "Agenda 2030"). As key partners for the achievement of Agenda 2030, one of the strategies that MNCs can introduce to achieve their sustainable manufacturing targets is the implementation of ZDM initiatives. Considering that decisions on sustainable manufacturing practice are made at top-level management through corporate boards, it is important to know which CG structure drives sustainable manufacturing using ZDM. This is because such knowledge can assist MNCs to strengthen the CG apparatus to facilitate the timely achievement of their SDGs targets directly or indirectly connected to sustainable manufacturing. However, little is known on the CG structures influencing ZDM.

Third, whereas the MDGs laid the foundation for achieving sustainable development, the SDGs were launched to consolidate the gains of the MDGs (Lodhia et al., 2022). However, in comparison to the MDGs period, the motivation for MNCs to bolster their CG structures to improve sustainable manufacturing practice such as ZDM may be higher in the SDGs period. As suggested by the stakeholder and legitimacy theories, MNCs may want to strengthen their CG structures to achieve responsible production in line with SDG 12 (responsible consumption and production), thereby demonstrating to stakeholders that they are responsible corporate citizens playing their part in the sustainable development agenda to gain stakeholders acceptance as a legitimisation strategy (Huang & Kung, 2010; Tetteh et al., 2022). Moreover, top MNCs are in high greenhouse gas (GHG) emitting countries (Tauringana & Moses, 2021),

and mainly operate in environmentally sensitive industries (i.e., primary and secondary activities). They are under more stakeholder pressure and public scrutiny to demonstrate increased resource-use efficiency and greater adoption of clean/ environmentally sound technologies and industrial processes through ZDM in line with SDG 9, target 9.4 (Lodhia et al., 2022). Since CG is a major self-regulation mechanism for discharging ethical and philanthropic duties with respect to ZDM (Carroll, 2015), MNCs may want to strengthen the CG structures to improve sustainable manufacturing through ZDM in the SDGs period. However, there is limited knowledge based on empirical analysis on how Agenda 2030 has impacted MNCs to commit to sustainable manufacturing using ZDM in the SDGs period in comparison to the MDGs period.

Against this backdrop, the current study seeks to investigate determinants of sustainable manufacturing practice using ZDM from the perspective of CG. Five CG structures which may uniquely affect sustainable manufacturing practice, as suggested by literature, were investigated, notably Board Independence, Meeting Attendance by Board Members, Duality of Chairperson/CEO Power, Board Gender Diversity, and Board Skills on Sustainable Manufacturing. The results show that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing are positively associated with ZDM Practice, whilst CEO Duality of Power has a negative impact. In the MDGs period, the foremost drivers of ZDM Practice are Board Independence, Board Gender Diversity, and Board Skills on Sustainable Manufacturing, whilst this shifted to Board Independence and Board Gender Diversity in the SDGs period.

2. Context and Theory

ZDM strategies aim at defect prevention and compensation (Psarommatis & Kiritsis, 2021). ZDM and sustainability are, thus, intertwined in the sense that the implementation of ZDM can assist an organisation to achieve sustainable development and sustainability targets (Psarommatis et al., 2022; Khakpour et al., 2024). ZDM ensures the optimal use of resources by reducing the amount of waste, recall, and rework (SDG 9: sustainable industrialisation), and this can lead to a decrease in the use of raw materials, other production resources, and energy (SDG 7: sustainable energy). Reduced use of energy on account of ZDM (SDG 7) can decrease emissions and release of harmful by-product that could have been generated in the process of reworking defective products (SDG 13: climate action). Further, ZDM can also support a

circular economy where resources are used more efficiently (Khakpour et al., 2024), and waste is minimised in the production process at every step of a product lifecycle to achieve sustainable production in line with SDG 12 (Psarommatis et al., 2024).

ZDM also adds a social sustainability dimension. ZDM can contribute to brand building, and can enhance customers' trust and confidence, foster brand loyalty, and encourage sustainable customer behaviour (Choi et al., 2023), thus contributing to the actualisation of SDG 12 on sustainable consumption. ZDM has financial benefits in terms of saving resources that would have been expended to correct defective products (SDG 8: sustainable economic growth). Organisations will, therefore, emplace CG mechanisms to improve ZDM practice and, by extension, achieve sustainable development goals. Our study relies on the stakeholder and legitimacy theories to explain CG determinants of ZDM as a sustainable manufacturing practice. The theories and their contextualisation to the study are covered next.

2.1 Stakeholder Theory

The stakeholder theory proposes that an organisation is normally made up of various stakeholders that are not only affected by the actions of the organisation but also have the power to influence the activities of the organisation (Doni et al., 2021). Although the owners/ shareholders of a company may have been responsible for setting up an organisation and engaging the directors to manage the affairs of the business on their behalf, the stakeholder theory postulates that the organisation is responsible to various stakeholder groups aside from the owners. The relevance of the various stakeholders stems from the consideration that different stakeholder groups wield significant influence which may affect the activities of the organisation (Chau & Gray, 2010). Thus, management should consider the interests of various stakeholders and how their actions may affect the organisation by analysing their levels of interests against their levels of power. In relating the stakeholder theory to the current debate on sustainable manufacturing, organisations will want to implement ZDM to improve product quality and satisfy the expectations of various stakeholders including their customers (who are the ultimate consumers of their products) and government (responsible for setting up and monitoring product quality).

Scholars have argued that voluntary compliance with best practice in production, such as ZDM, especially in climes where improving product quality is not mandated, is borne out of the need to enhance company image, gain societal approval, and satisfy stakeholders (Al-Hanshi et al., 2022), which is a legitimising strategy applied by companies (Belal & Cooper, 2011; Wen et

al., 2022). It is now common practice for multinational corporations to communicate global and local sustainability information in the various countries where they operate, including sustainable manufacturing practice because of the importance of satisfying various stakeholders irrespective of legal frameworks or institutional requirements in various jurisdictions (Momin & Parker, 2013). However, CG structures are critical for the successful implementation of sustainable manufacturing practice and the communication of the same to various stakeholders. Stakeholder pressure has contributed to increase in sustainability activities as well as the rendition of sustainability performance reports covering best practice in manufacturing such as ZDM (Nuskiya et al., 2021).

2.2 Legitimacy Theory

The legitimacy theory explains the process and strategies that organisations employ to seek societal endorsement or approval. Simply put, the legitimacy theory assumes that an organisation has no reason to exist unless its value aligns with the interests of the society (Magness, 2006). Following from this, requirements are imposed on organisations to justify their existence by proving their commitment for the advancement of the society. Sustainable manufacturing using ZDM aligns with the sustainable development agenda (particularly SDGs 9, 12, and 13). Therefore, involvement in sustainable manufacturing practice, such as ZDM, is seen as an effective strategy for manufacturing organisations to legitimise their existence and prove their relevance to the society to gain stakeholders' recognition and acceptance since they are contributing to the achievement of the sustainable development agenda. The society views the relationship with the company as a social contract, and the burden of proof is upon the company to demonstrate its commitment to environmental and social sustainability issues so that the society's perception of the company changes for the better. Embracing and implementing ZDM as a sustainable production strategy presents unique opportunities for manufacturing concerns to demonstrate their commitment to addressing sustainable development challenges.

Considering that legitimacy is purposive, intentional, and calculated (Suchman, 1995), manufacturing organisations seeking strategies to gain reputation among stakeholders in the society can showcase their sustainable manufacturing initiatives through the rendition of sustainability performance reports, whilst also providing evidence of their implementation of ZDM and environmental accountability (Mahadeo et al., 2011). Companies voluntarily

communicate their sustainable manufacturing practice in an effort towards substantiating the transparency and accountability of their performance (Alewine & Stone, 2013).

The domestication of the legitimacy theory to the current study suggests that various CG structures are emplaced to ensure that manufacturing organisations implement sustainable manufacturing practice such as ZDM to improve product quality, promote customer health and safety, and comply with responsible manufacturing/sustainable production regulations (Al-Hanshi et al., 2022). This is done for the purpose of legitimising their existence. Furthermore, sustainable manufacturing reports rendered to stakeholders are expected to be accurate, true, fair, and free from material misstatement (Habek & Wolniak, 2016). Corporate reputation improves when there is assurance about the credibility and reliability of such reports (Simnett et al., 2009). The provision of assurance by an independent auditor/inspector on the quality control process and sustainable manufacturing report of an organisation can enhance the quality of the information and improve corporate reputation as a legitimising strategy. Therefore, the rendition of an audited sustainability report communicating CG structure emplaced to support the implementation of sustainable manufacturing practice such as ZDM should enhance corporate legitimacy.

3. Hypotheses Development

3.1 Board Independence

Board independence is strengthened when there are more independent directors on the board to complement the efforts of the executive directors (Cucari et al., 2018). Considering that independent directors are not involved in the day-to-day activities of the organisation, they are expected to bring fresh perspectives and innovative thoughts to how the company is run. Their non-involvement in the routine activities of the organisation also implies that they would expectedly assess sustainable manufacturing issues such as ZDM without bias for the purpose of improving product quality and meeting customers' expectations (Ben-Amar et al., 2017). This consideration informs their injection into the board to protect stakeholders against the opportunistic tendencies of the executives in relation to sustainable manufacturing concerns. Their reputation as independent directors will also imply that they have the motivation to take decisions that will: (a) emplace quality control processes; (b) minimise the turning out of defective products; and (c) improve product quality. The stakeholder theory supports the argument that the appointment of independent directors is an effective monitoring mechanism that will ensure the introduction of quality control measures which diminish the production of defective items. Independent directors will want to protect their reputation as well as the

corporate image of the organisation by ensuring that defective products are not turned out into the market or associated with the organisation. In line with the legitimacy theory, manufacturing companies will want to appoint independent directors to be seen as making the right efforts to achieve ZDM. Studies have shown that board independence enhances corporate sustainability performance (e.g., Zhang et al., 2013; Ben-Amar et al., 2017; Cucari et al., 2018). This discussion informs the first hypothesis that:

> *H1: Board independence is positively associated with zero-defect manufacturing practice of MNCs.*

3.2 Meeting Attendance by Board Members

Board meetings are usually organised to create the forum for board members to engage on issues affecting the progress of the organisation, including product and process quality matters (Chakraborty, 2019). Since sustainable manufacturing is one of the critical issues confronting business entities in recent times (Gouda & Saranga, 2020), convening and attending regular board meetings facilitates the discussion of ZDM issues such as quality assurance, quality improvement, and predictive maintenance, among others. Such board meetings are regarded as quality circles where decisions on improving product quality are made. Stakeholders are aware that board meetings are critical in providing the platform for independent directors to engage executive directors on quality control issues affecting the interest of customers, host communities, pressure groups, and the government, amongst other stakeholder groups in the society. In line with the stakeholder theory, stakeholders are interested in the convening of board meetings and how well such meetings are attended by board members. To preserve corporate legitimacy, the organisation will want to be seen/perceived by stakeholders as an entity that provides the platform for board members to engage on process and product quality issues by convening regular board meetings and providing an avenue for independent board members to attend and engage with one another on issues that protect the interests of the stakeholders. Meeting attendance by board members has been empirically linked to improved sustainability outcomes (e.g., Allegrini & Greco, 2011; Chakraborty, 2019; Agyemang et al., 2020). Therefore,

> *H2: Meeting attendance by board members is positively associated with zero-defect manufacturing practice of MNCs.*

3.3 Duality of Chairperson and Chief Executive's Power

The complexity of activities in corporate entities requires that there should be an office holder that oversees the activities of the board (i.e., the Chairperson), whilst another person is responsible for managing the daily operations of the organisation (MD/CEO). This is because combining both functions of the board Chairperson and the CEO—i.e., CEO duality of power—may introduce control/management issues, conflicts of interest, and abuse of power (Lu & Wang, 2021). To ensure checks and balance, different persons should ordinarily wield the powers of Chairperson and the company CEO in line with best practice in CG as expected by various stakeholders (Harun et al., 2020). Considering that investment in zero-defect processes and technologies are capital-intensive and long-term in nature (Montoya-Torres et al., 2015; Fayyaz et al., 2024), executives may not ordinarily be motivated to make such investments because of the diminution in returns in the short run. Whilst such eco-friendly and sustainable manufacturing decisions should ultimately pay off in the run long, the huge initial outlay which may erode profit in the short run may be a disincentive to executives. Therefore, executive board members holding the dual position of Chairperson and Chief Executive may use their power to take sub-optimal decisions such as avoiding investment in sustainable manufacturing initiatives such as ZDM. To put checks in place against rent-seeking behaviour, corporate governance codes require the separation of the office of Chairperson from that of the Chief Executive to protect the interests of other stakeholders (aside from owners/shareholders) and to maintain corporate legitimacy. To recap, when both roles are combined in one person (giving rise to Chairperson/CEO duality of power), the resultant conflict of interest may diminish the sustainable manufacturing performance of an organisation. Empirical evidence abounds to support this argument (e.g., Harun et al., 2020; Lu & Wang, 2021; Nuskiya et al., 2021; Zhang et al., 2021). This discussion informs the next hypothesis that:

> *H3: CEO Duality of power is negatively associated with zero-defect manufacturing practice of MNCs.*

3.4 Board Gender Diversity

Branco and Rodrigues (2008) contend that the theme of board diversity correctly links into the structure of stakeholder theory. Since women's thinking differs from men's thought patterns according to gender socialisation theory (Haque et al., 2024), approaches to sustainable manufacturing issues by both genders may vary and influence the depth of a company's commitment to ZDM initiatives. Having an adequate number of female board members has

been noted to improve environmental sustainability performance because women are known to be generally eco-friendly, meticulous, and caring about others (Ben-Amar et al., 2017; Konadu et al., 2021). These traits would spur women to support/promote sustainable manufacturing practice such as ZDM. Moreover, women are also known to be naturally generous, more humanitarian, and more stakeholder-oriented (Javaid Lone et al., 2016; Ullah et al., 2019), and these traits influence their leaning towards protecting the health and safety of customers by insisting on product quality and minimising product defects. Furthermore, the meticulous nature of women would imply that they will not want their reputation and the image of the organisation that they manage to be associated with defective and poor-quality products. They will, therefore, strive for process improvement and product perfection by supporting ZDM practice. From the stakeholder theory perspective, stakeholders will be interested in gender-diverse boards because of the consideration that female board members may better protect their interests in sustainable manufacturing issues. Further, the inclusion of more female directors could be regarded as a legitimisation strategy to demonstrate gender balance on corporate boards (Solal & Snellman, 2019; Tingbani et al., 2020). A growing number of studies have shown that board gender diversity is positively associated with sustainable manufacturing practice (Chong et al., 2018; García-Sánchez et al., 2019; Ong et al., 2020; Kamarudin et al., 2021). Hence,

> *H4: Board gender diversity is positively associated with zero-defect manufacturing practice of MNCs.*

3.5 Board Skills on Sustainable Manufacturing

Board skills, competence, and experience on sustainable manufacturing may influence the nature and depth of ZDM practice or ZDM project that an organisation selects for implementation. This is because the successful execution of sustainable manufacturing projects requires expertise to manage time, resources, personnel, and relationships critical for their delivery (Akhtaruddin & Haron, 2010; Khakpour et al., 2024). Given the multidisciplinary nature of sustainable manufacturing issues, the stakeholder theory supports that the skill mix on the board should be balanced in such a manner that the board/top management team can deliver on its mandate of implementing ZDM projects. Considering the capital-intensive and long-term nature of quality improvement initiatives—such as quality assurance, predictive maintenance, procurement, and deployment of quality inspection technologies and associated digital technologies for quality prediction—having the requisite skills among board members

is a critical success factor in delivering the ZDM target for an organisation. The stakeholder theory will support the recruitment of directors with the technical skills required to supervise such projects to successful completion in the interests of all stakeholders affected by sustainable manufacturing practice. With respect to the legitimacy theory, demonstrating to stakeholders that the organisation possesses requisite skills in sustainable manufacturing practice/ has competent directors overseeing ZDM projects is an important aspect of the legitimisation process in the ZDM discourse. Thus, a high level of board skills on sustainable manufacturing should contribute to achieving ZDM. There is empirical evidence supporting the contention that the presence of knowledgeable and experienced board members coordinating the sustainability endeavours of an organisation contributes to achieving sustainable manufacturing targets (e.g., Sellami et al., 2018; Cancela et al., 2020; Elsayed & Ammar, 2020). Consequently, it is hypothesised that:

> *H5: Board skills on sustainable manufacturing is positively associated with zero-defect manufacturing practice of MNCs.*

3.6 Corporate Governance Structures and Sustainable Manufacturing in the MDGs and SDGs Periods

Whereas the MDGs laid the foundation for achieving sustainable development, the SDGs were launched to consolidate the gains of the MDGs (Lodhia et al., 2022). However, in comparison to the MDGs period, the motivation for MNCs to bolster their CG structures to improve sustainable manufacturing practice, such as ZDM, may be higher in the SDGs period based on four major arguments.

First, whilst the MDGs target developing countries, the SDGs affect both developed and developing countries (Oyewo et al., 2022). Bearing in mind that top MNCs are mostly based in developed countries, they may want to strengthen their CG structures to achieve responsible production in line with SDG 12, thereby demonstrating to stakeholders that they are responsible corporate citizens playing their part in the sustainable development agenda to gain stakeholders' acceptance as a legitimisation strategy (Tetteh et al., 2022).

Second, whilst the MDGs prevalently focus on social sustainability (with six out of eight goals on social sustainability issues) but with less emphasis on environmental issues, the scope of coverage for the SDGs permeates economic growth, social inclusion, and environmental protection. Considering that top MNCs are located in high greenhouse gas (GHG) emitting countries (Tauringana & Moses, 2021), and mainly operate in environmentally sensitive

industries (i.e., primary and secondary activities), they are under more stakeholder pressure and public scrutiny to demonstrate increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes in line with SDG 9, target 9.4 (Lodhia et al., 2022). Drawing from the stakeholder and legitimacy theories, they (top MNCs) will want to strengthen their CG structures to improve sustainable manufacturing by achieving ZDM. By so doing, they will be optimising the use of natural resources and minimising their environmental pollution/cleaning up their production externalities to satisfy stakeholders in line with SDG 13, and legitimising their existence (Aono & Okimoto, 2023).

Third, although the MDG 8 calls for the fostering of global partnership for development, the focus is on developed countries helping least developed and other low-income countries to achieve the development goals (Wagle, 2019). On the other hand, SDG 17 recognises the importance of the private sector in the achievement of the SDGs by calling for public–private partnerships in both developed and developing countries (United Nations, 2022). Since global companies are mainstream in the private sector, top MNCs have greater propensity to reinvigorate their governance structures to achieve SDGs relating to sustainable manufacturing (Muñoz, 2021) including, but not limited to, SDG 9 (industry, innovation, and infrastructure), SDG 12 (responsible production), and SDG 13 (climate action). Moreover, as the world's largest companies, top MNCs have the tendency to set the tone for sustainable manufacturing/ ZDM practices of other private sector organisations because their decisions have follow-on effects on the rest of the economy (Bashan & Notea, 2018). Arguing from the standpoint of the stakeholder and legitimacy theories, MNCs will want to demonstrate to stakeholders and other private sector entities that they are responsible corporate citizens by improving their sustainable manufacturing practice using ZDM to achieve SDGs outcomes. However, since CG is a major self-regulation mechanism for discharging ethical and philanthropic duties (Carroll, 2015), MNCs will want to strengthen the CG structures to improve sustainable manufacturing/ ZDM.

Fourth, the SDGs are far-reaching, more encompassing, and require greater levels of commitment and accountability on the parts of government and private sector organisations. Whilst the MDGs were developed by a group of experts, the SDGs were developed based on a consultation process among 193 UN member countries, civil societies, and other stakeholders (Wagle, 2019). Furthermore, whilst the MDGs covered 8 broad goals and have 21 targets and 60 indicators, the SDGs cover 17 goals, 169 targets, and 232 indicators (Wagle, 2019). This suggests a greater level of expectation among stakeholders for MNCs to comply—thus,

improvement in CG structure to enhance sustainable manufacturing practice by MNCs may be anticipated.

Taken together, MNCs are likely to be more responsive to the call to tackle sustainable manufacturing challenges by adopting ZDM in the SDGs period to satisfy the expectations of stakeholders and legitimise their existence as responsible corporate citizens contributing their quota to the achievement of SDGs. Since CG is a major self-regulating apparatus for fulfilling MNCs' philanthropic role of tackling sustainability challenges (Carroll, 2015), corporate commitment to sustainable manufacturing in the SDG period is likely to be stronger as MNCs may want to strengthen their CG structures to achieve the SDG outcomes. This discussion informs the hypothesis that:

> *H6: Ceteris Paribus, CG structures will have more impact on zero-defect manufacturing practice of MNCs in the SDGs period in comparison to the MDGs period.*

4. Methods

4.1 Research Design and Data

The study adopts a panel research design. The population of the study is Forbes Global 2000 companies, a database of the world's largest, most powerful MNCs ranked based on market value, revenue, assets, and profit. The Forbes selection has been widely employed in prior research (e.g., Martínez-Ferrero & García-Sánchez, 2017). A sample of the first 25% of the firms was selected, generating 500 companies. From this list, companies belonging to the financial and insurance sectors were excluded due to significant differences in their business in comparison to non-financial firms (Shu & Chiang, 2020; Konadu et al., 2021). Data were collected from multiple sources such as the London Stock Exchange Group, LSEG (formerly Refinitiv/ DataStream) databases, company websites, and the World Bank database. Prior studies have used data extracted from DataStream (Cheng et al., 2014). Supplementary information not available from the DataStream database was collected from the annual reports of the companies. Other national data relating to Gross Domestic Product (GDP) of countries and World Governance Indicators (WGI) were collected from the World Bank database. After excluding firms with no ZDM information, we ended up with 4583 firm-year observations that were processed for analysis.

4.2 Measurement of Variables

4.2.1 Dependent Variable

ZDM practice was measured using the Zero-Defect Manufacturing Practice index (ZDMPi) as the main measurement of variable. The ZDMPi was constructed by aggregating seven items typifying process and product quality according to the literature (Gnanaraj et al., 2012; Fayyaz et al., 2024), as detailed in Table 1: (i) quality management systems; (ii) ISO 9000; (iii) lean six sigma; (iv) resource use reduction; (v) customer satisfaction system; (vi) customer health and safety; and (vii) product responsibility monitoring. Whereas items (i) to (v) have an internal focus on quality management issues, items (vi) and (vii) have an external/customer orientation to quality management because they are an externally inclined approach to assessing quality from customers perspective. The seven items were compiled from the LSEG (Refinitiv) database. Considering that the maximum score obtainable for ZDM practice is 7, the ZDMPi for a year was computed as the percentage of the ratio of the ZDM score to the total score obtainable. This is mathematically expressed as:

$$\text{ZDMPi} = (ZDM\ score\ for\ a\ year)/\ 7 * 100\ . \qquad \textbf{(Eq. 1)}$$

ZDMPi has a positive polarity, meaning that higher index reflects robust ZDM practice.

To check the robustness of the results for the alternative measurement of the variable, product quality research and development (R&D) intensity was applied (Psarommatis et al., 2022; Khakpour et al., 2024). This was computed as expenditure on researching and developing new and sustainable manufacturing techniques aimed at achieving zero-defect divided by the revenue of a company in a financial year, expressed as a percentage. This is an indicator of how committed an organisation is to ZDM innovation and has a positive polarity. The item was computed by the researchers from the data available from the LSEG (Refinitiv) database.

Product responsibility performance was used as another alternative measure of the dependent variable (Choi et al., 2023; Psarommatis et al., 2024). Product responsibility category score, as extracted from the LSEG (Refinitiv) database, reflects a company's capacity to produce quality goods and services integrating the customer's health and safety, integrity, and data privacy. Product responsibility letter grade was converted to ranking, ranging from "D-" (coded 1) to "A+" (coded 12). Product responsibility performance has a positive polarity, meaning that higher scores reflect more commitment to ZDM. We use the logarithmic transformation of the scores in our regression analysis.

4.2.2 Independent Variables

The independent variables are corporate governance structure under investigation—namely, Board Independence (BIN), Meeting Attendance by Board Members (BMA), Duality of Chairperson/CEO Power (CED), Board Gender Diversity (BGD), and Board Skills on Sustainable Manufacturing (BDS). A summary of how they were measured is presented in Table 1.

4.2.3 Control Variables

Other corporate governance variables which may affect sustainable manufacturing of an organisation were included as control variables—notably, sustainability activities audit, AUD (Braam et al., 2016; Vogt et al., 2017), and sustainability performance pay, COM (Adel et al., 2019).

Studies have shown that firm attributes, alongside CG structures, affect sustainable manufacturing practice (Harun et al., 2020; Erin et al., 2021). Therefore, firm attributes such as firm size (FSZ), market presence (FVS), and profitability (FPR) were included as firm-level control variables (Orazalin & Mahmood, 2019; Tingbani et al., 2020). Considering that the current study is inter-country, country-level governance factors were also included as control variables to recognise national institutional factors that may impact the sustainable manufacturing practice of organisations as suggested by the institutional theory. The country-level control variables included in the study are Economic Development (CGD) and Country Governance (CWG) based on world Governance indicators (Harun et al., 2020; Lu & Wang, 2021). However, considering the contention surrounding the validity of the six governance indicators with respect to some indicators measuring the same construct, we factor-analysed the six indicators and used the average governance indicators in the regression model.

A full description of the variable measurements is presented in Table 1.

[Insert Table 1 about here]

4.3 Model Specification

Based on discussion in literature and theories invoked as the theoretical framework for the study, the proposed relationship between ZDM, CG structures, firm attributes, and country-level governance factors is specified in a panel multivariate regression model in equation 2:

$$ZDMP_{it} = \beta_0 + \beta_1 BIN_{it} + \beta_2 BMA_{it} + \beta_3 CED_{it} + \beta_4 BGD_{it} + \beta_5 BDS_{it} + \beta_6 AUD_{it} + \beta_7 COM_{it} + \beta_8 FSZ_{it} + \beta_9 FVS_{it} + \beta_{10} FPR_{it} + \beta_{11} PERIOD_{it} + \beta_{12} CGD_{it} + \beta_{13} CWG_{it} + \epsilon_{1it}$$

(Eq. 2)

where $ZDMP_{it}$ is Zero-Defect Manufacturing Practice; β_0 is constant for Model 1; $\beta_{1\text{-}12}$ are regressor coefficients; ϵ_{1it} is the stochastic error term; and other variables are as defined in Table 1. The regression Model in Equation 2 is used to estimate the baseline result.

4.4 Methods for Data Analysis

Descriptive statistics was used to perform univariate analysis and explore the characteristics of variables. Correlation analysis was performed to assess multicollinearity (Harun et al., 2020; Tingbani et al., 2020). The OLS regression method was used to analyse panel data in line with prior studies (Jamil et al., 2021; Konadu et al., 2021). After running post-estimation analysis, the Hausman test suggests that the fixed effect model is a better fit for the panel data. Thus, the result of the fixed effect model is reported. The fixed effect panel model recognises company-specific and industry-specific factors for each organisation in each country across the years. The model allows more observations and ensures that only time-varying variables account for the changes in the dependent variable. All the time-invariant unobservable factors were accounted for in the intercept, also referred to as the fixed effect (Baltagi, 1998). Two-stage least squares (2SLS)/ instrumental variable regression, propensity score matching (PSM), and Heckman two-step model were used to assess the robustness of results.

5. Results

5.1 Descriptive Analysis

The result in Table 2 shows that there is significant difference in the CG structures, firm-attributes, and country-level governance factor in the MDGs and SDGs periods. The governance structures also appear to have improved in the SDGs period in comparison to the MDGs period, notably in terms of Board Independence, Meeting Attendance by Board Members, Separation of Chairperson/CEO Role, Board Gender Diversity, and Sustainability Activities Audit. However, Board Skills on Sustainable Manufacturing appears to have diminished between the MDGs (M = 47.63%) and SDGs (M = 43.72%) periods. Sustainability Performance Pay also appears to have been generally less popular in the SDGs period (M = 0.28) in comparison to the MDGs period (M = 0.31). In sum, differences in CG structures and

firm attributes in the MDGs and SDGs periods among the MNCs provide a rich context for examining the CG drivers of sustainable manufacturing practice in the MDGs and SDGs period. Table 3 suggests that collinearity is not a concern because of the low correlation strength between the variables.

[Insert Table 2 about here]

[Insert Table 3 about here]

5.2 Baseline Result: Corporate Governance Determinants of Zero-Defect Manufacturing Practice (combined for MDGs and SDGs periods)

The result from the analysis of the influence of CG structures on ZDM Practice, combined for the MDGs and SDGs periods, is reported in Table 4.

[Insert Table 4 about here]

The result in Table 4 shows that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, Board Skills on Sustainable Manufacturing, Sustainability Activities Audit, and Sustainability Performance Pay are positively associated with ZDM Practice, whilst CEO Duality of Power has a negative impact. Further, all the variables are statistically significant across the three measures of ZDM Practice (i.e., Zero-Defect Manufacturing Practice index, Product Quality R&D Intensity, and Product Responsibility Performance), except Board Gender Diversity that has no significant impact on Product Quality R&D Intensity. This result supports the acceptance of H1, H2, H3, H4, and H5.

With reference to the firm-level control variables, firm size (in terms of revenue) and market visibility (in terms of market capitalisation) consistently emerge as positive significant determinants of ZDM practice across the three measures, implying that large-sized and market-visible firms may be able to implement robust environmental, social and governance (ESG) initiatives because of the availability of resources to them. The result also reveals that the MDGs–SDGs period dichotomy has a significant impact on ZDM across the three dimensions of ZDM Practice. Following this, we conduct subsample analysis to examine the CG drivers of ZDM Practice in the MDGs and SDGs periods respectively. The result of the analysis is presented in Table 5 (the MDGs period) and Table 6 (the SDGs period).

5.3 Corporate Governance Determinants of Zero-Defect Manufacturing Practice in the MDGs period

The analysis of the determinants of ZDM Practice in the MDGs period is as reported in Table 5.

[Insert Table 5 about here]

The result in Table 5 for the MDGs period shows that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing are positively associated with ZDM practice, whilst CEO Duality of Power has a negative impact. Further, all the variables are statistically significant across the three measures of ZDM practice. The result supports the acceptance of H1, H2, H3, H4, and H5. The result in Table 5 for the MDGs period is similar to that of Table 4, except that Board Gender Diversity consistently emerged as the strongest determinant of ZDM practice (in terms of beta coefficient) across the three ZDM practice measures (Zero-Defect Manufacturing Practice Index, Product Quality R&D Intensity, and Product Responsibility Performance) in the MDGs period (Table 5), whilst it is the strongest determinant under the Product Responsibility Performance in Table 4 (column 3). The impact of firm size on ZDM practice is positive and statistically significant under two ZDM practice measures, whilst market presence is positive and significant under Product Quality R&D Intensity, thus confirming the above result in Table 4 that firm size and market visibility drive the implementation of ZDM initiatives.

5.4 Corporate Governance Determinants of Zero-Defect Manufacturing Practice in the SDGs period

The result of the analysis of the determinants of ZDM Practice in the SDGs period is reported in Table 6.

[Insert Table 6 about here]

The result in Table 6 for the SDGs period shows that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing, are positively associated with ZDM Practice, whilst CEO Duality of Power has a negative impact. Whereas Board Independence is statistically significant across the three ZDM Practice measures, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing are statistically significant across two measures (Zero-Defect

Manufacturing Practice Index and Product Responsibility Performance). Taken together, the statistical significance of the variables across at least two measures of ZDM Practice confirms that they are significant drivers of ZDM Practice. The beta coefficient reveals that the foremost drivers of ZDM Practice are Board Independence and Board Gender Diversity (Table 5, column 1). Firm size and market presence consistently emerge as positive significant determinants of ZDM Practice across two measures, implying that large-sized and market-visible firms have higher propensity to implement robust ESG initiatives.

5.5 Comparison of the impact of Corporate Governance Structures on Zero-Defect Manufacturing Practice in the MDGs and SDGs Periods

In comparing the impact of Corporate Governance Structures on Zero-Defect Manufacturing Practice in the MDGs and SDGs Periods, we rely on the beta coefficients, t-statistics, and model coefficients of determination (R^2). The beta coefficients of Meeting Attendance by Board Members, and Board Skills on Sustainable Manufacturing declined in the SDGs period in comparison to the MDGs period for the main measurement of dependent variable (Table 5 column 1, and Table 6 column 1). The beta coefficients of Board Independence and Board Gender Diversity improved between the MDGs (Table 5) and SDGs periods (Table 6). CEO Duality of Power has a greater impact in diminishing ZDM Practice in the SDGs period (Table 6) in comparison to the MDGs period (Table 5).

Based on the strength of the t-statistic (i.e., beta coefficient / standard error), the impact of the CG structures appears to be stronger in the MGDs period (Table 5) in comparison to the SDGs period (Table 6). Board Independence has greater impact in the MDGs period (t-stat. = 6.360/ 1.212 = 5.248) when compared to the SDGs period (t-stat. = 7.645/ 2.293 = 3.334). Meeting Attendance by Board Members has greater impact in the MDGs period (t-stat. = 4.240/ 0.677 = 6.263) when compared to the SDGs period (t-stat. = 3.390/ 0.648 = 5.231). Board Gender Diversity has greater impact in the MDGs period (t-stat. = 9.059/ 2.552 = 3.550) when compared to the SDGs period (t-stat. = 10.726/ 3.259 = 3.291). Board Skills on Sustainable Manufacturing has greater impact in the MDGs period (t-stat. = 5.884/ 0.794 = 7.411) when compared to the SDGs period (t-stat. = 3.106/ 0.886 = 3.506). However, CEO Duality of Power has greater impact in the SDGs period (t-stat. = -3.137/ 0.800 = 3.921) when compared to the MDGs period (t-stat. = -1.913/ 0.551 = 3.472).

Going by the coefficients of determination (R^2), the R^2 for the MDGs period for the main dependent variable (Zero-Defect Manufacturing Practice Index) is 31.5%, whereas that of the SDGs period is 26.6%. Further, whilst the R^2 for the alternative measures range from 15.7% to 30.8% in the MDGs period, the corresponding figures for the SDGs period range from 4.9% to 25.5%.

Overall, the results show that the impact of CG structures on ZDM Practice vary in the MDGs and SDGs periods. As the CG structures do not consistently have higher impact in the SDGs period when compared to the MDGs period, we reject H6.

5.6 Robustness Check

5.6.1 Treatment of Endogeneity using two-stage least squares (2SLS)/ instrumental variable regression

The literature suggests that simultaneity may occur between board gender diversity and corporate sustainability performance/ZDM Practice (Tingbani et al., 2020; Konadu et al., 2021). Simultaneity, as a dimension of endogeneity problem, implies that two variables may influence each other. In other words, variable X (Board Gender Diversity) causes Y (ZDM Practice), but Y (ZDM Practice) may also cause X (Board Gender Diversity). To treat the endogeneity problem, we apply two-stage least squares (2SLS)/instrumental variable regression (Konadu et al., 2021; Ullah et al., 2021; Tawiah et al., 2024a). Following the approach used in prior studies, industry board gender diversity was applied as the instrument for firm-level board gender diversity (Solal & Snellman, 2019; Xie et al., 2023). The result of the 2SLS/instrumental variable regression analysis is presented in Table 7. In the first stage (column 1), we regress the endogenous variable (Board Gender Diversity) on the instrument and other variables. We validate the appropriateness of the instrumental variable using the Anderson canonical correlation LM statistic for under-identification test, the Stock–Yogo weak ID test for weak identification test, and the Sargan–Hansen J statistic for over-identification test (Tawiah et al., 2024a). The Anderson LM. Statistic 221.32 is significant ($p < 0.01$), and the Cragg–Donald Wald F-statistic (43.11) is greater than the highest Stock–Yogo weak ID test critical values (19.28). The Sargan–Hansen J statistic p value is not statistically significant ($p = 0.213 > 0.10$). The results are consistent with the acceptable thresholds and statistical significance, confirming the validity of the instrument. In the second stage, we use the predicted

value of Board Gender Diversity from the first stage as the instrument to estimate the equation using the main measurement of the dependent variable (column 2).

[Insert Table 7 about here]

The result in Table 7 (column 2) is consistent with Table 4 in which Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing are positively associated with ZDM practice, whilst CEO Duality of Power has a negative impact. With respect to the firm-level control variables, firm size and market presence consistently emerge as positive significant determinants of ZDM Practice confirming the prior results that that large-sized and market-visible firms have higher propensity to implement robust ESG initiatives. The result is also consistent with Table 4 with respect to the impact of the MDGs/ SDGs periods on ZDM Practice. The coefficient of determination of the model in Table 7 column 2 (R^2 = 41.2%) has a comparable size with that of Table 4 column 1 (R^2 = 44.4%), confirming that the result is robust and comparable to the baseline result after correcting for endogeneity.

5.6.2 Treatment of endogeneity using propensity score matching

Board gender diversity consistently emerged as a significant, positive determinant of ZDM Practice (Table 4). To examine the robustness of the result to potential endogeneity between Board Gender Diversity and ZDM Practice, propensity score matching (PSM) with nearest neighbour (NN) matching was applied. Using the median score of board gender diversity (17.25%), firms were split into treatment group (firms with board gender diversity scores > 17.25%) and control group (firms with board gender diversity scores ≤ 17.25%). The result of the PSM is presented in Table 8.

[Insert Table 8 about here]

We compare the attributes (Mean) of the treatment group (column 1) with the control group (column 2) before the matching and the result shows statistically significant differences (column 3).

The matching procedure reduced our sample to 2956, with equal number of observations in the treatment (1478) and control (1478) groups, respectively. To check that our matching is satisfactory, we run a post-match descriptive analysis as reported in columns 4–6. The result shows no significant difference in the attributes (Mean) of the treatment group (column 4) and

the control group (column 5) as indicated by the t-statistic (column 6), implying that firms in the treatment and control groups have similar attributes in the matched sample. The first stage of the PSM procedure, whereby we use the binary categorisation of treatment/control as the dependent variable (i.e., Board Gender Diversity Dummy) is reported in column 7. The result from the second stage of the PSM reported in column 8 reveals that our baseline result remains valid in terms of how CG structures affect ZDM Practices.

5.6.3 Treatment of Sampling Bias using the Heckman two-step selection model

It is possible that our result is biased by sample selection, as analysis is presented for firms with information on ZDM Practice from the data source (i.e., 4583 firm-year observations). To address selection bias, we employ the two-step Heckman correction procedure (Heckman, 1979; Oyewo et al., 2024; Tawiah et al., 2024b). The result of the analysis is presented in Table 9.

[Insert Table 9 about here]

In the first stage of the two-step Heckman correction procedure (column 1), we derive a model for the probability of implementing ZDM Practice (*Zero-Defect Manufacturing_dummy*) using a probit regression. *Zero-Defect Manufacturing_dummy* takes a value of '1' if a firm implements ZDM in a year, and '0' otherwise. We include all firms (those with and without ZDM disclosure) in our sample, making a total of 5112 observations. To satisfy the exclusion criteria in the first stage, we use industry Board Gender Diversity to instrument firm-level Board Gender Diversity (Solal & Snellman, 2019; Xie et al., 2023). Thereafter, we regress the *Zero-Defect Manufacturing_dummy* on all variables in our baseline model as shown in column 1 (Table 9) and derive the Mills ratio to account for selection bias. In the second stage (column 2; Table 9), we regress ZDM Practice on all independent variables, Mills ratio, and control variables. The result is consistent with the baseline result, implying that our result is robust to sample selection bias.

6. Discussion

To ensure a robust discussion, the findings are thematically discussed under three subheadings: (i) CG structures influencing ZDM Practice; (ii) CG structures affecting ZDM Practice in the MDGs and SDGs periods, and (iii) magnitude of impact of CG structures on ZDM Practice in the MDGs and SDGs periods.

6.1 CG Structures influencing Zero-Defect Manufacturing Practice

The result shows that, in the MDGs period, the SDGs period, and at the aggregate level (i.e., MDGs and SDGs periods combined), Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing are positively associated with ZDM Practice, whilst CEO Duality of Power has a negative impact.

The result that Board Independence has a positive impact on ZDM Practice is consistent with the literature that having a reasonable number of independent directors on the board enhances ZDM Practice (Zhang et al., 2013; Cucari et al., 2018). This supports the stakeholder theory which posits that stakeholders will prefer to appoint independent directors to strengthen board performance as a strategy for achieving sustainability outcomes (Ben-Amar et al., 2017). The positive impact of Meeting Attendance by Board Members on ZDM Practice aligns with the submission in the literature that attending and participating in board meetings provides a medium for debating ESG issues, and such robust discussions/ strategy sessions yield a positive outcome of improving ZDM Practice (Chakraborty, 2019; Agyemang et al., 2020).

The positive impact of Board Gender Diversity corroborates the argument that the inclusion of female board members boosts ZDM Practice because heterogeneity in the thought process and the biological make-up of women differ from those of men, as women have a propensity to support more ESG initiatives known to alleviate sufferings in the society (Ong et al., 2020; Kamarudin et al., 2021). In alignment with the stakeholder theory, the clamour for the appointment of female board members is a strategy that can protect the interest of outside/external stakeholders. The appointment of female board members is also a strategy for assuring stakeholders that the organisation is committed to improving ESG performance as a legitimising strategy (García-Sánchez et al., 2019).

The positive association between Board Skills on Sustainable Manufacturing and ZDM Practice confirms that the level of knowledge and competence among board members on ESG issues is critical to delivering ESG outcomes (Cancela et al., 2020; Erin et al., 2021). Thus, stakeholders will want to be sure that board members directing the affairs of the organisation can deliver on ZDM targets. CEO Duality of Power is negatively associated with ZDM Practice, and this is consistent with the result of prior studies (Harun et al., 2020; Lu & Wang, 2021; Nuskiya et al., 2021). This implies that combining the powers and responsibilities of the Chairperson with the CEO creates conflicts of interest which could erode ZDM Practice (Zhang

et al., 2021). In alignment with the demand of stakeholders for more accountability, corporate entities typically split the office of the Chairperson from that of the CEO.

In relation to governance variables used as controls, the positive impact of Sustainability Activities Audit on ZDM Practice confirms that independent and external assessment of ESG activities contributes to the achievement of ESG outcomes (Braam et al., 2016; Vogt et al., 2017). The result provides motivation for companies to engage in Sustainability Activities Audit to gain stakeholders' confidence and legitimise their existence (Tetteh et al., 2022). Sustainability Performance Pay for board members also has a positive impact, implying that companies can motivate board members by linking their pay to the attainment of ZDM metrics (Zhou, 2019; Lu & Wang, 2021). Although there is limited evidence in literature that Sustainability Performance Pay can enhance ZDM Practice, the current study provides some empirical evidence in this regard.

Firm size and market presence consistently emerged as positive significant determinants of ZDM Practice, implying that large-sized and market-visible firms have higher propensity to implement robust ESG initiatives perhaps because (i) they have more resources to implement ESG and (ii) they implement ESG projects as a legitimisation strategy to maintain their competitive position. The result provides evidence that availability of resources is crucial for implementation of ESG initiatives.

6.2 CG structures affecting Zero-Defect Manufacturing Practice in the MDGs and SDGs periods.

The result generally shows that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, and Board Skills on Sustainable Manufacturing, are positively associated with ZDM Practice in the MDGs period, the SDGs period, and at the aggregate level. However, the magnitude of the impact of the variables differs across the periods.

Based on beta coefficients, the foremost drivers of ZDM Practice in the MDGs period are Board Independence, Board Gender Diversity, and Board Skills on Sustainable Manufacturing (Table 5). However, this shifted to Board Independence and Board Gender Diversity in the SDGs period (Table 6). Board Independence and Board Gender Diversity consistently appear as foremost drivers in both MDGs and SDGs periods. Meanwhile, at the aggregate level in the baseline result (Table 4), Board Independence, Board Gender Diversity, and Board Skills on Sustainable Manufacturing (Table 4) are top-ranking determinants. The consistency of Board

Gender Diversity as a significant determinant at the aggregate level and at the MDGs and SDGs periods is confirmed by the robustness test result using 2SLS/ instrumental variable regression (Table 7), propensity score matching (Table 8), and the Heckman two-step selection procedure (Table 9).

In Table 2, the prominence of the sustainability activities audit in the SDGs period (M = .640) in comparison to the MDGs period (M = .460) may be explained by the demand for greater accountability and a greater level of transparency by stakeholders from corporate entities with the coming into effect of the sustainable development agenda (Muñoz, 2021). As suggested by the legitimacy theory, corporate entities are increasingly seeking strategies to demonstrate commitment to ESG issues (Lodhia et al., 2022), and one of the foremost avenues through which this can be achieved is to have their sustainability activities audited by an independent auditor (Tetteh et al., 2022). Not surprisingly, therefore, the practice of embedding audited sustainability/ ESG report within the annual report is gaining traction, and organisations are using such reports to communicate CG mechanisms emplaced to achieve sustainability targets, including sustainable manufacturing practice such as ZDM. Similarly, corporate entities are increasingly issuing stand-alone sustainability/ESG report with comments provided by sustainability activities/ESG auditors as a strategy for strengthening transparency and addressing the claims of green-washing/ white-washing of sustainability reports. The publishing of audited ESG/ sustainability report, especially with the coming into effect of the sustainable development agenda, aligns with both the stakeholder theory and legitimacy theory. Whilst ESG reports will be audited to provide reasonable assurance to stakeholders that such report presents a true and fair view of the company's sustainability endeavours (to address concerns about whitewashing of sustainability reports), making the reports publicly available, with independent comments from sustainability activities Auditors, is a strategy for legitimising existence, inspiring public confidence and gaining stakeholders acceptance.

6.3 Magnitude of impact of CG structures on Zero-Defect Manufacturing Practice in the MDGs and SDGs Periods

Result in Table 4 shows that the MDGs/SDGs period dichotomy has a significant impact on ZDM Practice, with the SDGs period recording higher ZDM Practice in comparison to the MDGs period (Table 2). However, the disaggregated result reveals that the CG structures have a greater impact on ZDM Practice in the MDGs period (Table 5) in comparison to the SDGs period (Table 6). Going by the coefficients of determination (R^2), the R^2 in the MDGs period

for the main dependent variable (Zero-Defect Manufacturing Practice index) is 31.5% (Table 5), whilst the corresponding value for the SDGs period is 26.6%. Relatedly, the R^2 in the MDGs (SDGs) period for the alternative measures of ZDM Practice are 15.7% (4.9%) and 30.8% (25.5%) for Product Quality R&D Intensity (Product Responsibility Performance) respectively.

Although ZDM Practice has significantly improved between the MDGs and SDGs periods (Table 2), a closer examination of the results in Table 5 and Table 6 shows that the beta coefficients of certain CG structures such as Meeting Attendance by Board Members, and Board Skills on Sustainable Manufacturing declined in the SDGs period in comparison to the MDGs period (i.e., results for the main measure of ZDM Practice—Zero-Defect Manufacturing Practice index in Table 5 column 1, and Table 6 column 1). The result in Table 2 provides some insight on the diminished impact of the CG structures on ZDM Practice in those periods. Although there was a slight improvement in Meeting Attendance by Board Members in the SDGs period (M = 0.781) in comparison to the MDGs period (M = 0.676), the improvement is not robust enough as to cause appreciable improvement in ZDM Practice (Table 2). Board Skills on Sustainable Manufacturing reduced in the SDGs period (M = 0.437) in comparison to the MDGs period (M = 0.476), and this partly explains the diminished impact of the variable in the SDGs period (b = 3.106; Table 6 column 1) in comparison to the MDGs period (b = 5.884; Table 5 column 1).

The beta coefficients of Board Independence and Board Gender Diversity improved between the MDGs (Table 5) and SDGs periods (Table 6), and this could be linked to uplift in those CG structures. Notably, Board Independence improved from 76.1% (MDGs) to 77.6% (SDGs), whilst the corresponding improvement in Board Gender Diversity was from 14.05% (MDGs) to 22.00% (SDGs) in Table 2.

Although there is slight improvement in separating the role of the Chairperson from that of the CEO between the MDGs (M = 0.540) and SDGs (M = 0.500) periods (Table 2), the severity of the negative impact of CEO Duality of Power on ZDM Practice is still higher in the SDGs period (b = -3.137; Table 6) in comparison to the MDGs period (b = -1.913; Table 5). This implies that the practice of combining the dual role of Chairperson and CEO in one person is still popular among MNCs in the SDGs period, accounting for its diminished impact on ZDM Practice.

For governance control variables, Sustainability Activities Audit witness improvement in the SDGs period (M = 0.640) compared to the MDGs period (M = 0.460) but the impact of Sustainability Activities Audit on ZDM Practice diminished between the MDGs period (b = 5.474; Table 5, column 1) and SDGs period (b = 3.439; Table 6, column 1). The practice of Sustainability Performance Pay declined between the MDGs (M = 0.310) and SDGs (M = 0.280) periods, and this may have contributed to the diminished impact of Sustainability Performance Pay in the SDGs period (b = 2.337) compared to the MDGs period (b = 4.292).

7. Conclusion

This study investigates the impact of CG structures on ZDM Practice in the MDGs and SDGs periods with a view towards assessing the extent to which the United Nations sustainable development agenda has affected corporate commitment to sustainable manufacturing practice. The results show that Board Independence, Meeting Attendance by Board Members, Board Gender Diversity, Board Skills, ESG Audit, and ESG-driven Compensation are positively associated with ESG performance, whilst CEO Duality of Power has a negative impact. In the MGDs period, the foremost drivers of ZDM are Board Independence, Board Gender Diversity, and Board Skills on Sustainable Manufacturing, whilst this shifted to Board Independence and Board Gender Diversity in the SDGs period. Whereas the impact of Board Independence and Board Gender Diversity improved between the MDGs and SDGs periods, the impact of Meeting Attendance by Board Members and Board Skills on Sustainable Manufacturing diminished in the SDGs period in comparison to the MDGs period. CEO Duality of Power has a greater impact in diminishing ZDM Practice in the SDGs period (Table 6) in comparison to the MDGs period (Table 5). Taken together, the study concludes that corporate governance is a notable determinant of sustainable manufacturing using ZDM. Organisations seeking to improve sustainable manufacturing practice may, therefore, consider strengthening their corporate governance mechanisms to demonstrate responsible manufacturing in line with stakeholders' expectations and to preserve corporate legitimacy.

Although ZDM practice improved in the SDGs period in comparison to the MDGs period, the relatively higher impact of the CG structures in the MDGs period in comparison to the SDG period suggests that other factors may have been responsible for the difference. That CG structures are not contributing as much to ZDM practice during the SDGs period in comparison to MDGs period suggests that companies need to reinvigorate their CG structures to achieve sustainable manufacturing, especially in the areas where the coefficients of CG structures

weakened in the SDGs period, notably Meeting Attendance by Board Members, Board Skills on Sustainable Manufacturing, Sustainability Activities Audit, and Sustainability Performance Pay. However, the overall positive impact of CG structures on ZDM in the SDGs period implies that CG is a veritable tool which can be used to improve sustainable manufacturing practices. Although sustainability performance pay is still nascent, the study presents evidence that it has the potential to improve sustainable manufacturing. Corporate entities may, therefore, start looking into how managers can be incentivised to achieve sustainable manufacturing outcomes by linking executive pay to ZDM. Drawing from the result that there is slight improvement in separating the role of the Chairperson from that of the CEO between the MDGs and SDGs periods (Table 2), segregating Chairperson responsibilities from those of the CEO is a welcome development which should be encouraged to have the desired impact of improving commitment to sustainable manufacturing/ ZDM. Although results from this study show no notable difference in the impact of CEO Duality of power on ZDM Practice in MDGs and SDGs period despite slight decline in CEO Duality of Power between both periods, with more rigorous implementation of CEO/Chairperson power split, the benefits may materialise eventually. To enhance sustainable manufacturing practice/ ZDM, it is recommended that the gains of the positive impact of Board Independence and Board Gender Diversity on ZDM between the MDGs and SDGs periods should be consolidated by strengthening the corporate governance structure in these aspects.

Our findings make several contributions to both literature and policies. First, we contribute to the literature by investigating CG structures that have been suggested as key determinants of sustainable manufacturing practice in literature but not rigorously investigated within the context of ZDM—notably, Board Independence, Meeting Attendance by Board Members, CEO Duality of Power, Board Gender Diversity, and Board Skills on Sustainable Manufacturing. Our study exposes the impact of these CG structure on ZDM. Second, the study empirically validates the relevance of stakeholder theory and legitimacy theory in explaining the motivation of corporate entities to embrace sustainable manufacturing practice/ ZDM by emplacing corporate governance structures. Third, our study provides evidence on the actions that MNCs are taking to achieve sustainable manufacturing/ ZDM through CG structures. Knowledge on CG determinants of ZDM can inform policy formulation on strengthening CG structure to achieve sustainable development goals related to sustainable consumption and manufacturing such as SDG 7 (sustainable energy), SDG 9 (sustainable industrialisation), SDG 12 (sustainable production and consumption), and SDG 13 (climate action). Finally, our study

presents evidence that CG is a valuable tool that can be used to improve sustainable manufacturing practice. As the deadline for the actualisation of Agenda 2030 approaches, stakeholders are taking a keener interest in the steps and strategies that can be implemented to achieve the SDGs targets. The reinvigoration of relevant CG structures, as demonstrated by the results of this study, can be an effective strategy for achieving such SDGs targets.

The current study is not without limitations, and these have implications for future studies. Considering that the study deploys a panel research design, the limitations of panel data analysis apply such as measurement errors, endogeneity concerns, sample selection bias, and the generalisability of results. However, we took steps to address these limitations. With respect to measurement error, ZDM Practice was measured using Zero-Defect Manufacturing Practice index (ZDMPi) as the main measurement of variable. Alternative measurements such as product quality research and development (R&D) intensity (alternative measurement 1), and product responsibility performance (alternative measurement 2) were applied in our analysis. We addressed the endogeneity problem by using two-stage least squares (2SLS)/ instrumental variable regression and propensity score matching (PSM). We addressed sample selection bias by employing the Heckman two-step selection model. Our study focused on top 500 global non-financial firms, and the results are generalisable to multinational corporations operating in non-financial industries. Future studies may consider investigating corporate governance structures affecting ZDM practice in financial service firms and medium-sized firms to enhance the generalisability of the results. It will also be beneficial to examine the institutional factors influencing ZDM practice. ZDM could result in financial gains as suggested in the literature—empirical evidence on the association between ZDM practice and financial performance would also contribute to knowledge on the relative advantage of ZDM as an innovation. Finally, studies investigating innovation attributes influencing the adoption of ZDM practice would enrich the literature on the relevance of the diffusion of innovation theory to the sustainable manufacturing practice discourse.

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List of Tables

Table 1: Measurement of Variables

Variables	Measurement
Zero-Defect Manufacturing Practice (Main measure of dependent variable)	Zero-Defect Manufacturing Practice index (ZDMPi) computed based on the summation of seven items, implying that the maximum score obtainable in a year is 7. If the company has a policy in respect of each of the following, it is issued a '"TRUE" and coded '1' for the item; otherwise, it is assigned a "FALSE" and coded '0' for the item. (i) Quality Management Systems: Does the company apply quality management systems, such as the European Foundation for Quality Management (EFQMs), Lean Manufacturing, Kaizen and continuous improvement process, predictive maintenance, TQM, quality inspection technologies, or any other similar quality principles? (ii) ISO 9000: Does the company have an ISO 9000 certification or any industry-specific certification (QS-9000–automotive, TL 9000–telecommunications, AS9100–aerospace, ISO/TS 16949–automotive, etc.)? (iii) Lean Six Sigma: Does the company apply the Six Sigma? - only an internal quality system or framework is considered, including information on Good Manufacturing Practice (GMP); information on quality certifications (like ISO 9000 and EFQMs) is not considered under this dimension (iv) Resource use reduction policy: Does the company have a policy in place to reduce the use of materials, energy, or water, and to find more eco-efficient solutions of minimising defective products and improving supply chain management? (v) Customer Satisfaction System: Does the company have a mechanism in place to monitor customer satisfaction? Does the company publish/report the percentage of customer satisfaction? Does the report contain the overall percentage of customers who are satisfied, including customer engagement rate and customer satisfaction index? (vi) Customer Health and Safety Policy: Does the company have a policy to protect customer health and safety by striving to minimise defective products? - processes or initiatives in place by which it strives to market products which are fostering benefits to the consumer's health and safety rather than putting it at risk—includes product-related initiatives (vii) Product Responsibility Monitoring: Does the company monitor the impact of its products or services on consumers or the community more generally? - any evidence that the company monitors the impact of its products and services on consumers are considered—the focus to be on responsible product manufacturing with minimal product defect, consider internal industry monitoring, surveys, audits, or any other form of measurement relating to product quality monitoring. Whereas items (i) to (v) have an internal focus on quality management issues, items (vi) and (vii) have an external/ customer orientation to quality management because they are

	an externally inclined approach to assessing quality from the perspective of the customers. ZDMPi for a year computed as percentage of the ratio of ZDM score to the total score obtainable.
Product Quality Research and Development (R&D) intensity (Alternative measure of dependent variable 1)	Research and development expenditure on improving product quality and innovation and reducing defective products as a ratio to revenue per annum expressed in percentage.
Product Responsibility Performance (Alternative measure of dependent variable 2)	Product responsibility category score reflects a company's capacity to produce quality goods and services integrating the customer's health and safety, integrity, and data privacy. Product Responsibility letter grade converted to ranking, ranging from "D-" (coded 1) to "A+" (coded 12). Logarithmic transformation of the scores.
Board Independence	Proportion of Non-executive Directors (NEDs) to total board size expressed in %.
Meeting Attendance by Board Members	Average Meeting Attendance by Board Members in a year expressed in %.
CEO Duality of Power	If Chairman also serves as the CEO, there is duality of power, and then a code of 1 is assigned; if otherwise, there is non-existence of duality of power, then code 0 is assigned.
Board Gender diversity	Number of Female Directors to total board size in a year expressed in %.
Board skills on sustainable manufacturing on sustainability	Percentage of board members who are knowledgeable about sustainability issues relative to total directors on the board.
Sustainability Activities Audit	If Sustainability Activities report is audited = 1, otherwise =0.
Sustainability Performance Pay	If payment of executive board members pay is connected to sustainability performance = 1, otherwise = 0.
Size of Firm (proxy 1)	Revenue (logarithmic transformation of,)
Size of Firm (proxy 2)	Market capitalisation (logarithmic transformation of,)
Firm Performance	Return on Total Assets ratio (ROTA).
MDG/SDG periods	MDGs period = 2006-2015; SDGs period = 2016–2020.
Gross Domestic Product	Gross Domestic Product (GDP) (logarithmic transformation of,).
Governance Quality (global view)	Factor analysis of six World Governance Indicators (WGI) based on World bank data.

Table 2: Descriptive statistics on Zero-Defect Manufacturing Practice and Corporate Governance Structures in the MDGs and SDGs Periods

Variables	Period	Mean	Std. Dev.	Std. Err.	F ratio
Zero-Defect Manufacturing Practice index	MDGs	58.767	20.925	.386	186.610***
	SDGs	67.150	18.021	.444	
	Total	61.778	20.330	.300	
Product Quality R&D Intensity	MDGs	52.185	19.049	.351	145.111***
	SDGs	59.082	17.756	.437	
	Total	54.662	18.885	.278	
Product Responsibility Performance	MDGs	7.58	2.531	.047	180.891***
	SDGs	8.57	2.175	.054	
	Total	7.93	2.456	.036	
Board Independence	MDGs	.761	.2478	.004	4.873**
	SDGs	.776	.190	.004	
	Total	.766	.228	.003	
Meeting Attendance by Board Members	MDGs	.676	.371	.006	92.414***
	SDGs	.781	.318	.007	
	Total	.714	.356	.005	
Duality of Chairperson/CEO Power	MDGs	.540	.499	.009	6.101**
	SDGs	.500	.500	.012	
	Total	.520	.499	.007	
Board Gender Diversity	MDGs	.140	.111	.002	443.055***
	SDGs	.220	.139	.003	
	Total	.169	.128	.002	
Board Skills on Sustainable Manufacturing	MDGs	.476	.249	.005	27.067***
	SDGs	.437	.233	.006	
	Total	.462	.244	.004	
Sustainability Activities Audit	MDGs	.460	.499	.009	140.730***
	SDGs	.640	.479	.012	
	Total	.530	.499	.007	
Sustainability Performance Pay	MDGs	.310	.464	.009	4.747**
	SDGs	.280	.451	.011	
	Total	.300	.460	.007	

*** p<0.01, ** p<0.05

Table 3: Correlation analysis and Multicollinearity Check

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Board Independence (1)	1.000											
Meeting Attendance by Board Members (2)	.301***	1.000										
CEO Duality of Power (3)	.033**	.026*	1.000									
Board Gender Diversity (4)	.443***	.271***	.069***	1.000								
Board Skills on Sustainable Manufacturing (5)	-.252***	-.012	.077***	-.091***	1.000							
Sustainability Activities Audit (6)	-.008	-.014	-.125***	.092***	-.136***	1.000						
Sustainability Performance Pay (7)	.290***	.200***	.031**	.305***	-.022	.189***	1.000					
Revenue (8)	.047***	.016	-.029**	.034**	-.080***	.257***	.113***	1.000				
Market Capitalisation (9)	.199***	.079***	.055***	.191***	-.046***	.175***	.152***	.518***	1.000			
Return on Total Assets (ROTA) (10)	.088***	.011	.028*	.068***	.080***	-.061***	-.028*	-.123***	.281***	1.000		
Gross Domestic Product (11)	.273***	.068***	.131***	.351***	-.044***	.025*	.210***	.042***	.196***	-.049***	1.000	
World Gov. Indicator (12)	.041***	.143***	.017	.267***	.103***	.019	.111***	-.015	.009	-.112***	.507***	1.000

*** p<0.01, ** p<0.05, * p<0.10

Table 4: CG Structures and Zero-Defect Manufacturing Practice (Baseline Result)

	(1)	(2)	(3)
Variable	**Zero-Defect Manufacturing Practice**	**Product Quality R&D Intensity**	**Product Responsibility Performance**
Board Independence	5.894*** (1.093)	5.940*** (1.476)	.655*** (.134)
Meeting Attendance by Board Members	3.487*** (.491)	2.311*** (.662)	.453*** (.060)
CEO Duality of Power	-2.059*** (.437)	-1.192** (.590)	-.273*** (.053)
Board Gender Diversity	5.646*** (1.870)	-.207 (2.524)	.805*** (.230)
Board Skills on Sustainable Manufacturing	5.157*** (.637)	6.448*** (.859)	.660*** (.078)
Governance variables (control)			
Sustainability Activities Audit	4.931*** (.430)	4.069*** (.581)	.612*** (.053)
Sustainability Performance Pay	4.064*** (.346)	2.579*** (.467)	.524*** (.042)
Firm-level Variables (control)			
Revenue	10.453*** (.953)	3.550*** (1.286)	1.229*** (.117)
Market Presence	3.494*** (.738)	5.805*** (.996)	.440*** (.090)
Return on Total Assets (ROTA)	-.070** (.034)	-.033 (.046)	-.009** (.004)
Period (MDGs/SDGs)	3.402*** (.409)	2.925*** (.552)	.409*** (.050)
Country Governance (control)			
Gross Domestic Product	36.741*** (3.345)	37.208*** (5.008)	4.089*** (.456)
World Gov. Index (factor analysed)	-.080 (.068)	.253*** (.092)	-.012 (.008)
Firm Effect	YES	YES	YES
Year Effect	YES	YES	YES
R^2	0.444	0.223	0.433
N	**4,583**	**4,583**	**4,583**

Standard error in parentheses
*** p<0.01, ** p<0.05

Table 5: CG Structure and Zero-Defect Manufacturing Practice in the MDGs period

	(1)	(2)	(3)
Variable	**Zero-Defect Manufacturing Practice**	**Product Quality R&D Intensity**	**Product Responsibility Performance**
Board Independence	6.360*** (1.212)	7.015*** (1.602)	.696*** (.149)
Meeting Attendance by Board Members	4.240*** (.677)	3.014*** (.895)	.566*** (.083)
CEO Duality of Power	-1.913*** (.551)	-1.895*** (.728)	-.265*** (.068)
Board Gender Diversity	9.059*** (2.552)	9.885*** (3.373)	1.310*** (.315)
Board skills on sustainable manufacturing	5.884*** (.794)	6.524*** (1.050)	.712*** (.098)
Governance variables (control)			
Sustainability Activities Audit	5.474*** (.542)	4.489*** (.716)	.670*** (.067)
Sustainability Performance Pay	4.292*** (.410)	2.069*** (.543)	.555*** (.050)
Firm-level Variables (control)			
Revenue	4.681*** (1.304)	-.573 (1.724)	.629*** (.161)
Market Presence	1.208 (.951)	3.742*** (1.257)	.182 (.117)
Return on Total Assets (ROTA)	-.007 (.045)	-.019 (.060)	-.003 (.005)
Country Governance (control)			
Gross Domestic Product	52.321*** (4.989)	51.221*** (6.594)	5.602*** (.617)
World Gov. Index (factor analysed)	-.644*** (.126)	-.365** (.167)	-.074*** (.015)
Firm Effect	YES	YES	YES
Year Effect	YES	YES	YES
R^2	0.315	0.157	0.308
N	**2,937**	**2,937**	**2,937**

Standard error in parentheses
*** p<0.01, ** p<0.05

Table 6: CG Structures and Zero-Defect Manufacturing Practice in the SDGs period

	(1)	(2)	(3)
Variable	**Zero-Defect Manufacturing Practice**	**Product Quality R&D Intensity**	**Product Responsibility Performance**
Board Independence	7.645***	9.698**	1.117***
	(2.293)	(4.150)	(.294)
Meeting Attendance by Board Members	3.390***	1.533	.382***
	(.648)	(1.174)	(.083)
CEO Duality of Power	-3.137***	-1.311	-.408***
	(.800)	(1.449)	(.102)
Board Gender Diversity	10.726***	-2.339	1.163***
	(3.259)	(5.899)	(.419)
Board Skills on Sustainable Manufacturing	3.106***	2.459	.483***
	(.886)	(1.603)	(.113)
Governance variables (control)			
Sustainability Activities Audit	3.439***	4.179***	.530***
	(.741)	(1.341)	(.095)
Sustainability Performance Pay	2.337***	1.807*	.347***
	(.515)	(.932)	(.066)
Firm-level Variables (control)			
Revenue	12.326***	5.731	1.319***
	(2.017)	(3.651)	(.259)
Market Presence	2.092*	2.699	.277*
	(1.196)	(2.165)	(.153)
Return on Total Assets (ROTA)	-.067	.013	-.006
	(.047)	(.086)	(.006)
Country Governance (control)			
Gross Domestic Product	63.140***	38.157***	7.842***
	(7.337)	(13.279)	(.943)
World Gov. Index (factor analysed)	.154*	.646**	.012
	(.081)	(.147)	(.010)
Firm Effect	YES	YES	YES
Year Effect	YES	YES	YES
R^2	0.266	0.049	0.255
N	**1,646**	**1,646**	**1,646**

Standard error in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Two-stage least squares (2SLS) Regression on CG Structures and Zero-Defect Manufacturing Practice

	(1)	(2)
	1st stage of 2SLS	2nd stage of 2SLS
Variable	**Board Gender Diversity**	**Zero-Defect Manufacturing Practice**
Board Gender Diversity (industry)	.159*** (.059)	-
Board Gender Diversity (predicted value)	-	6.063*** (.703)
Board Independence	2.108** (.893)	5.336*** (1.125)
Meeting Attendance by Board Members	8.740*** (1.279)	4.278*** (1.169)
CEO Duality of Power	2.028*** (.489)	-1.398*** (.244)
Board Skills on Sustainable Manufacturing	4.121* (2.366)	5.162*** (.925)
Governance variables (control)		
Sustainability Activities Audit	5.174*** (.611)	3.824*** (.668)
Sustainability Performance Pay	3.533*** (.541)	3.228*** (.477)
Firm-level Variables (control)		
Revenue	8.311*** (.602)	6.598*** (1.001)
Market Presence	.315 (.649)	.262*** (.070)
Return on Total Assets (ROTA)	1.956* (1.023)	-.352*** (.063)
Period (MDGs Vs. SDGs)	.132*** (.019)	1.822*** (.588)
Country Governance (control)		
Gross Domestic Product	1.496 (1.048)	1.056 (.886)
World Gov. Index (factor analysed)	.315*** (.044)	.404*** (.063)
Firm Effect	YES	YES
Year Effect	YES	YES
R^2	0.235	0.412
Anderson LM. statistic	221.32***	-
Stock-Yogo weak ID test	19.28	-
Cragg–Donald Wald F-stat.	43.11	-
Sargan–Hansen J stat.(p value)	0.213	-
N	**4,583**	**4,583**

Standard error in parentheses
*** p<0.01, ** p<0.05

Table 8: Propensity score matching result on CG Structures and Zero-Defect Manufacturing Practice

	Pre-match sample univariate analysis of Treatment group and Control group			Post-match sample univariate analysis of Treatment group and Control group			1st stage of PSM	2nd stage of PSM
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Treatment group (Mean)	Control group (Mean)	Compare Mean of Treatment and Control (t statistic)	Treatment group (Mean)	Control group (Mean)	Compare Mean of Treatment and Control (t statistic)	DV = Board Gender Diversity Dummy	DV = Zero-Defect Manufacturing Practice
Zero-defect Manufacturing Practice	60.523	61.723	2.76**	60.218	61.113	2.35**	-	-
Board Gender Diversity (pscore)	-	-	-	-	-	-	-	7.680*** (1.580)
Board Independence	.776	.842	6.97***	.854	.851	-0.65	8.657*** (2.062)	6.669*** (1.141)
Meeting Attendance by Board Members	.822	.776	-2.46**	.801	.814	1.77	2.949*** (.808)	2.682*** (.561)
CEO Duality of Power	.543	.578	2.21**	.563	.573	0.71	-.076** (.032)	-1.435** (.109)
Board Skills on Sustainable Manufacturing	.441	.438	-.05	.446	.457	1.65	1.110** (.535)	4.895*** (.894)
Sustainability Activities Audit	.543	.564	2.64*	.562	.534	-1.91	4.950*** (1.039)	3.294*** (.947)
Sustainability Performance Pay	.406	.476	4.78**	.447	.452	1.51	6.349*** (.721)	4.764*** (.660)
Revenue	4.240	4.346	2.01*	4.850	4.855	.18	1.501* (.892)	5.409** (2.694)
Market Presence	4.833	4.875	3.05**	4.368	4.374	.82	-6.063*** (.703)	3.230*** (.048)
Return on Total Assets (ROTA)	5.474	5.468	-2.29**	5.475	5.473	-.09	.007 (.050)	-.227** (.105)
Period (MDGs Vs. SDGs)	-	-	-	-	-	-	1.044*** (.015)	-4.536*** (.561)
Gross Domestic Product	-	-	-	-	-	-	-.884** (.353)	13.181*** (2.744)
World Gov. Index (factor analysed)	-	-	-	-	-	-	2.653*** (.759)	-.523 (.929)
Firm Effect	-	-	-	-	-	-	NO	YES
Year Effect	-	-	-	-	-	-	YES	YES
R^2	-	-	-	-	-	-	0.271	0.385
N	1,869	2,714	-	1,478	1,478	-	4,583	2,956

Coefficients are reported, with standard errors in parentheses.
*** p<0.01, ** p<0.05 * p<0.10

Table 9: Heckman two-step selection result on CG Structures and Zero-Defect Manufacturing Practice

	(1)	(2)
	1st stage	**2nd stage**
Variable	**Zero-Defect Manufacturing_dummy**	**Zero-Defect Manufacturing Practice**
Board Gender Diversity (industry)	2.141*** (.070)	-
Board Gender Diversity	-	3.383*** (.485)
Mills_Ratio	-	2.413*** (.788)
Board Independence	3.130*** (.070)	5.611*** (1.064)
Meeting Attendance by Board Members	.242*** (.058)	.198*** (.060)
CEO Duality of Power	-.298*** (.067)	-.946*** (.338)
Board Skills on Sustainable Manufacturing	.407*** (.099)	4.895*** (.894)
Governance variables (control)		
Sustainability Activities Audit	1.232*** (.035)	3.911*** (1.265)
Sustainability Performance Pay	1.058** (.025)	3.149** (1.284)
Revenue	.213*** (.063)	2.361* (1.360)
Market Presence	.162*** (.039)	.909* (.490)
Return on Total Assets (ROTA)	-.157*** (.052)	-.197** (.083)
Period (MDGs Vs. SDGs)	.113*** (.029)	1.110** (.535)
Country Governance (control)		
Gross Domestic Product	.020 (.047)	.024 (.022)
World Gov. Index (factor analysed)	.241*** (.056)	.296*** (.097)
Firm Effect	NO	YES
Year Effect	YES	YES
R^2	-	0.404
Pseudo R-square	0.235	-
N	**5,112**	**4,583**

Standard error in parentheses
*** p<0.01, ** p<0.05 * p<0.10