# THE MEDIATING ROLE OF INTERNAL ORGANISATION FACTORS BETWEEN EXTERNAL ENVIRONMENT AND GREEN INNOVATION ADOPTION AMONG MANUFACTURING SMALL AND MEDIUM ENTERPRISES: THE MODERATING EFFECT OF BIG DATA ANALYTICS

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## ABSTRACT

The depletion of natural resources and environmental concerns have gained attention at the individual and economic levels in the recent years. These environmental concerns compelled the manufacturing sector all over the globe to adopt environmentally friendly practices, also termed green innovation adoption. The manufacturing sector covers the essential needs of each individual, and their demand increases on a daily basis. The green innovation adoption rate in manufacturing Small and Medium-sized Enterprises (SMEs) among developed countries is much higher than the adoption rate of such practices among developing nations. Therefore, there was a need to study the factors influencing manufacturing SMEs to adopt green innovation in developing countries like Malaysia, as the manufacturing industry plays an essential role in the Malaysian economy. This study examines the external and internal factors influencing eco-innovation adoption. The external environmental factor includes the institutional and market environment. The institutional environment was further narrowed down into formal and informal institutions. Moreover, the market environment was classified into customer green demand and green competition. Additionally, the internal organisational factors were classified as green dynamic capabilities and organisational green culture. Specifically, the objectives of the present study were: (i) to assess the influence of the institutional environment and the market environment on green innovation adoption; (ii) to investigate the mediating role of internal organisational factors; and (iii) to examine the moderating effect of big data analytics capability. This study is theoretically grounded in institutional theory, organisational cultural theory, and dynamic capability theory, providing a multi-

level lens to explain how external pressures, internal resources, and technological capabilities interact to foster green innovation adoption. This study adopts a survey research design targeted on manufacturing Malaysian SMEs using the quota sample technique. The sample consists of 204 manufacturing SMEs collected from Selangor, Johor, Kuala Lumpur, Perak, and Penang and analysed using the PLS-SEM.

The results show that institutional and market environments had a positive and significant impact on green innovation adoption among manufacturing SMEs, whereas green dynamic capability mediated the relation between market environment and green innovation adoption. Additionally, organisational green culture mediated the relationship between green competition and green innovation adoption. Lastly, big data analytics capabilities moderated between green dynamic capabilities and green innovation adoption. The findings of the current research contribute theoretically by integrating three complementary perspectives to explain green innovation adoption in manufacturing SMEs, and practically by offering actionable insights for policymakers and SME managers. For instance, policymakers can design targeted incentives and regulatory frameworks to strengthen institutional roles, while SME managers can cultivate internal organisational factors and invest in data-driven capabilities to enhance competitiveness and sustainability. These findings serve as a benchmark for developing more effective strategies to accelerate green innovation adoption in Malaysia's manufacturing sector and for extending future research on green innovation adoption.

Keywords: Green innovation adoption; external environment factors; green

dynamic capability; organisational green culture; big data analytics capabilities

Subject Area: GE300-350 Environmental management

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# CHAPTER ONE

# INTRODUCTION

This chapter provides comprehensive background knowledge on the subject matters being discussed in this study. It contains prior theoretical work on green innovation, institutional and market environment, internal organisational factors, and manufacturing small and medium-sized enterprises (SMEs). This chapter will provide the briefing and explain how this study can fill gaps by providing the following details.

## 1.1 Background of the Study

### 1.1.1 Green Innovation

Based on current global assurances, global greenhouse gas emissions are expected to rise by almost 23% percent over the recent decade (Rooper, 2024). The manufacturing sector contributes the largest share of pollution that is 44% in the developing countries (Pacini & Attafuah-Wadee, 2022). Natural resource depletion, degradation of the environment, and the need for sustainable development have pushed green innovation to the forefront of global priorities.

Green innovation, green innovation practices, and green innovation adoption are interrelated but distinct concepts in the realm of environmental sustainability. Green innovation pertains to the development of environmentally friendly solutions, including sustainable products and technologies (Solaja et al., 2020). In contrast, green innovation practices encompass the strategies,

methodologies, and approaches employed to develop these eco-friendly innovations (J. F. de Medeiros et al., 2018). Meanwhile, green innovation adoption signifies the practical integration of these innovations into real-world business operations, bridging the gap between theoretical potential and practical implementation (Yu et al., 2022).

While these concepts share a common goal of promoting environmental sustainability, each plays a unique role in the journey toward a greener and more sustainable future. This study focuses on green innovation adoption rather than green innovation or green innovation practices because adoption is the crucial stage where firms move from potential to actual implementation, ensuring tangible environmental and economic impact. While green innovation pertains to the creation of environmentally friendly solutions, and green innovation practices involve the strategies and methodologies that support their development, green innovation adoption determines whether these innovations are effectively integrated into real-world business operations.

Globally, industries are placing more and more emphasis on sustainability (Noranarttakun & Pharino, 2021b). The awareness of environmental issues has raised the need for sustainable solutions (C.-H. Wang, 2019). In order to lessen their environmental impact, businesses are embracing ecological-friendly strategies. According to the Statista report by Laricchia (2023), the investigation forecasts that the green technological product market throughout the globe will expand due to organisations that are strictly working on sustainability principles between 2021 and 2030. In terms of financial value,

the green technology and sustainability market were estimated to be 29.0 billion dollars by the end of 2024. Furthermore, it will grow with a compound annual growth rate of more than 23.5% between 2024 and 2033 and will reach its peak of 193.9 billion US dollars by 2033 (Dimension Market Research, 2024).

Likewise, global partnerships and collaborations have made it easier to share information, best practices, and technical breakthroughs for adopting green innovations (Yu et al., 2022). Public-private collaborations and initiatives like the Sustainable Development Goals (SDGs) of the United Nations have been crucial in spreading knowledge and promoting the use of sustainable technology and practices. The SDGs have also had a favourable effect on the global economy as they encourage economies around the world to embrace environmentally friendly and sustainable practices. SDG 9 refers to industry, innovation, and infrastructure (United Nations, 2022). SDG 9 endorses domestic technology development, research and innovation, sustainable industrialisation, investments in research and development, and improved resource efficiency in developing nations, which can be improved more through the adoption of green innovation in the manufacturing sector. According to the SDG Report (2023), Goal 9 indicates that the global manufacturing value added (MVA) share of total GDP grew from 16.2% in 2015 to 16.9% in 2021. Due to the robust international demand for the region's manufacturing and exports, Eastern and South-Eastern Asia regions observed an increase in their share from 25.5 to 26.1 percent over the same period. Moreover, SDG 12 emphasises responsible consumption and production (United Nations, 2022). It promotes sustainable practices, waste reduction and recycling, eco-design, and

sustainable supply chains in the manufacturing sector that can be achieved by the adoption of green innovation. Furthermore, Goal 12 highlights that domestic material consumption (DMC) assesses the entire quantity of materials directly used by an economy to satisfy domestic and international demand for products and services. Globally, total domestic material consumption increased by more than 69 percent between 2000 and 2022, reaching 96.0 billion metric tons in 2022. That is each person wasted an average of 79 kilograms annually (United Nations, 2024). Eastern and South-Eastern Asia, Europe, and North America accounted for nearly 70% of the world's DMC. Eastern and South-Eastern Asia saw a tremendous increase in DMC, from 31% in 2000 to 43% in 2019. These stats highlight the importance of environmentally friendly practices to encounter depletion of resources. These cooperative initiatives have established a favourable environment for manufacturers to implement green innovation by granting access to resources and expertise. Both SDG goals (9 and 12) are relevant for this study as they provide a structured pathway for manufacturing SMEs to adopt green innovations that contribute to environmental sustainability. In this study, these SDGs guide the investigation into green innovation adoption by leveraging to meet global sustainability goals, particularly in the context of manufacturing SMEs.

In conclusion, worldwide statistics and trends show that the increase in wastage, natural resource depletion, and productivity has highlighted the importance of green innovation and sustainable practices around the world, which increases the demand for green market annually (Laricchia, 2023; Precedence Research, 2022).

### 1.1.2 Malaysian Manufacturing SMEs

SMEs fall within a specified size range regarding their yearly sales turnover, number of employees, or other financial indicators. SMEs in the manufacturing sector are enterprises that have a full-time staff count of no more than 200 or a sales turnover of no more than RM50 million. The remaining SMEs (which include services and other sectors) are enterprises with annual sales turnover of RM20 million in the services and other sectors or a number of full-time employees under 75 (SME Corp Malaysia, 2022). Furthermore, manufacturing SMEs are divided into small and medium-sized categories. Small-sized enterprises encompass 5 to 75 employees or a sales turnover of RM15 million, whereas medium-sized enterprises have no more than 200 employees or a sales turnover of RM50 million (SME Corp Malaysia, 2022).

In Malaysia, the services sector contributes 59.2 percent to the overall GDP, followed by 23.4 percent from the manufacturing sector (Department of Statistics Malaysia [DOSM], 2024a). The agriculture sector contributes 6.6 percent to GDP respectively (DOSM, 2024a). As per the performance report, compared to SMEs activities, the manufacturing sector is still the second highest source of the SMEs' GDP, weighing 20.2% (DOSM, 2024b). The manufacturing SMEs contribute 8.1% of the overall GDP, having 26,731 established firms (SME Corp. Malaysia, 2024). The annual growth of the entire manufacturing sector as per 2023 SMEs' GDP due to the manufacturing SMEs contribution has increased by 6.0% with an overall GDP growth of 8.1%, which

is the second highest compared to other economic sectors (SME Corp. Malaysia, 2024). With regards to the SMEs export performance, since the pandemic hit the nation, the manufacturing sector has emerged as the main contributor to the value of SMEs exports (SME Corp. Malaysia, 2022). Following a significant decline of 33.1% in 2020, SMEs exports increased by 16.3% in 2022 (SME Corp. Malaysia, 2024). SMEs exports reached a value of RM144.5 billion, with SMEs in the manufacturing sector providing the majority of the rise. In the manufacturing sector, SMEs exports performed significantly better in 2022, increasing by 19.5% (SME Corp. Malaysia, 2024).

#### 1.1.2.1 Malaysian Manufacturing SMEs and Green Innovation Adoption

In the matter of sustainability, Malaysia recognises the significance of being green in terms of sustainable environment (Yacob et al., 2019). Malaysia has pledged its support for international agreements and treaties, such as the Paris Climate Change Agreement and the United Nations Sustainable Development Goals (SDGs). According to the SDG Report (2023) and SDG Report (2025), Malaysia is also slightly improving in SDGs 9 and 12. The improvements mainly occur in SDG 9 in logistics performance, internet usage, and publications (number of published academic articles), whereas in SDG 12, exports of plastic waste and $SO_2$ emissions (associated with acid rain and industrial pollution) have been improved. In SDG 9, Malaysia has gained 1.66% growth in technological product manufacturing to support sustainable innovation in 2020 compared to 2019 (SDG Report, 2024). Additionally, in SDG 12, Malaysia has improved its national material recycled rate from 30.7%

in 2020 to 31.5% in 2021 (DOSM, 2021). These commitments demonstrate the country's desire to address environmental issues and promote sustainable development. Malaysia has been striving to increase its capacity for renewable energy. They intend to employ more renewable energy sources collectively and have established objectives for generating renewable energy. Malaysia encourages the use of solar, biomass, and hydropower as renewable energy sources (Green Technology Master Plan [GTMP], 2017). In addition, Malaysia raised its mitigation goals, setting an unconditional goal to reduce its GDP's carbon intensity by 45% by 2030 compared to 2005 levels, which was 138.04 million tons (GTMP, 2017). Moreover, Malaysia's manufacturing industry is essential to its economic development. The government of Malaysia has introduced several programs, laws, initiatives, and schemes to support manufacturing SMEs in implementing green practices, such as following the SDGs, ISO 14000 environmental management systems standards, and funding schemes for green technology.

According to the World Economic Forum (2022), the SMEs and mid-sized companies contribute 70% of global pollution, whereas manufacturing SMEs alone account for 40% of the air pollution (World Economic Forum, 2025). However, only 0.4% of the manufacturing SMEs implement environmental management systems. Malaysia reports 0.7% of the global greenhouse gas emissions, but the manufacturing industry is the third largest contributor of these emissions with 9% (Malaysian Green Technology and Climate Change Corporation [MGTC], 2022a). However, Malaysian manufacturing SMEs face specific challenges in implementing green

innovation. According to Yacob et al. (2019), key environmental sustainability concerns in these manufacturing SMEs include difficulties in water conservation, energy management, and waste management. Additionally, one of the barriers is due to the organisational cultural values and beliefs in green innovation adoption (Pan et al., 2022). Many manufacturing SMEs also lack capabilities and expertise and may consider implementing green innovation adoption difficult and complicated due to the lack of knowledge and limited resources (Yu et al., 2022). Despite these barriers, Malaysian SMEs in the industrial sector have several potentials to implement green innovations. By adopting sustainable practices, manufacturing SMEs may improve their brand's image, gain access to new markets that place a premium on sustainability, meet the demand of green consumers, and save costs via increased resource efficiency (Qiu et al., 2020; C. Wang et al., 2020; Yuan & Cao, 2022). Additionally, green innovation adoption may operate as a point of differentiation, allowing SMEs to stand out in a highly competitive sector and attract customers who care about the environment.

Conclusively, the Malaysian manufacturing sector is the second-highest contributor in terms of SMEs GDP or overall GDP (SME Corp. Malaysia, 2022). It not only contributes to production but always helps the economy by producing a significant number of employments. The government of Malaysia supports manufacturing SMEs to adopt green innovation with the help of various initiatives and programs like the green technology master plan, large companies sourcing from SMEs, and increasing market access opportunities (SME Corp Malaysia, 2022).

### 1.1.3 Institutional and Market Environment

As global concerns about environmental sustainability evolve, the adoption of green innovation has gained pace internationally, driven by several key aspects of business, society, and governmental strategies throughout the world. The development of green technology and practices has been advanced because of collaborations between formal and informal institutions (Mubarak et al., 2021). They share techniques and resources that enable businesses to overcome common challenges to implement green innovation. Governments all over the globe have established regulations and guidelines into effect in order to encourage the adoption of green innovations. For instance, the Green Deal of the European Union and China's aim to become carbon neutral by 2060 demonstrate strong governmental backing for sustainable practices (Borrell, 2020). The Net Zero Emissions by 2050 (Global Innovation Index, 2022) can be achieved by integrating emission removal with emission reduction. Also, the Environmental Quality Act 1974 outlines pollution prevention, reduction, control, and environmental improvement provisions (GTMP, 2017). Lastly, ISO 14000 environmental management standards also provide guidelines, and technical reports to reduce environmental impacts and follow environmental safety measures (Amaranti et al., 2019; Ren et al., 2018; Yang et al., 2019). Such programs have not only globally forced manufacturing companies to incorporate green innovation but have also given them a framework to implement environmental friendly practices.

In recent years, the conservation of the environment and sustainability has also gotten more attention in Malaysia. The government of Malaysia has established several programs and laws to encourage manufacturing SMEs to embrace and promote environmental sustainability due to which industrial sector pollution has decreased by 20.8% in 2021 as compared to the year 2020 (DOSM, 2022). The implementation of SDGs and investment opportunities in manufacturing areas like the production of sustainable packaging, biodegradable materials, and low-carbon decentralised solutions for waste treatment are a few of these programs (Malaysian Investment Development Authority [MIDA], 2020). Likewise, green technology funding scheme, green technology financing scheme, green investment tax allowance, green technology master plan, green income tax exemption, national green technology policy, and the sustainable energy development authority (SEDA) are a few initiatives taken by the government of Malaysia to promote environmental friendly adoptions in manufacturing SMEs. The green technology financing scheme offers financial support of total funding earmarked up to RM2.0 billion, primarily for green technology component cost financing (MGTC, 2020). Green investment tax allowance of 100% of a capital expense on approved green technology assets, and in the year of assessment, it will offset 70% against statutory income (MGTC, 2022b). Similarly, the green technology master plan states the strategic plans for the development of green technologies to build a resource and carbon-efficient economy (GTMP, 2017). Furthermore, informal institutions influence the societal and commercial conceptions of green innovation. Large companies in Malaysia are starting to include sustainability in their operations and plans as they realise how important it is for the

conservation of the environment (Fauzi et al., 2021; Qiu et al., 2020). Many businesses have set up sustainability departments or programs to promote environmental and social responsibility inside their enterprises (Razali & Jamil, 2023). The collaboration between enterprises, governments, and non-governmental organisations (NGOs) is also rising to solve sustainability concerns. Besides that, Malaysia's scheduled waste increased by 4.5%, approximately 7,505.2 thousand metric tonnes in 2021 compared to the year 2020 when it was 7,185.2 thousand metric tonnes (DOSM, 2022), whereas the industrial sector produces the third largest greenhouse gas emissions (MGTC, 2022a; Our World in Data, 2019).

Additionally, the market environment for manufacturing SMEs is affected by various factors. Customer green demand and competition for ecological sustainability (commonly known as green competition) are two of the most significant elements. Due to the growing demand for ecological friendly alternatives from customers who care about the environment, manufacturing companies need to adopt green innovation. This customer green demand pressurises manufacturing SMEs to produce, implement, and promote ecological-friendly products in order to be more sustainable (S. K. Singh et al., 2022). Customers throughout the world are becoming more aware of how their purchases affect the environment and prefer goods and services from manufacturing companies that show a commitment to sustainability (S.-T. Lin & Niu, 2018; S. A. de Medeiros et al., 2020). According to a Simon-Kucher & Partners survey conducted in 2021, in order to lessen their influence on the environment, 78% of customers worldwide are willing to modify their

purchasing habits and demand environmental friendly products (Jain et al., 2021). Moreover, the majority of the respondents in a 2020 McKinsey US consumer sentiment survey about purchasing environmentally and ethically sustainable products responded that they would pay more for a product with sustainable packaging (Feber et al., 2020). The Simon-Kucher & Partners survey further states that in the past five years, 85% of customers worldwide have grown "greener" in their purchases and demand of goods and services from manufacturing firms devoted to having a positive social and environmental impact (Jain et al., 2021). Likewise, consumers in Malaysia are growing more concerned with environmental issues and thoughtful about their purchases (Ignatius, 2022). As per a Business Today news article, 60% of consumers in Malaysia think businesses should put ecological protection ahead of profits, and 47% of consumers think governments should do the same (Ignatius, 2022). They are impulsively exploring environmental friendly and sustainable goods and services. As a result, manufacturing SMEs that provide such a requirement gain a competitive edge and could attract a broader consumer base. In order to satisfy customer green demand, business organisations are being forced to prioritise environmental friendly practices (Joshi & Dhar, 2020; Zameer et al., 2020).

The presence of green competition within a manufacturing industry can function as a catalyst for green innovation adoption. As more companies adopt green innovation, others could do the same in order to stay competitive. The development of leaders in the green industry may serve as a role model and motivate SMEs to embrace sustainable technology and methods. Additionally, the Malaysian manufacturing SMEs needs to increase in the number of

certifications and eco-labels that confirm the sustainability credentials of goods and services. These certifications, like the Green Label from the Malaysian Green Technology Corporation, assure customers that the products they buy adhere to strict environmentally friendly standards (MGTC, 2020). These certifications impact the market environment by motivating businesses to implement eco-friendly activities to earn and keep their certifications (Pichlak & Szromek, 2022) in order to survive in a competitive market.

In conclusion, institutional and market environment elements affect businesses to adopt green innovation. Furthermore, it offers insights and suggestions for encouraging green practices by assessing market dynamics. Malaysian manufacturing SMEs must adopt green innovation through strategic interventions and partnerships across stakeholders, improving their competitive edge in the global green market and helping them to ensure environmental sustainability to meet the customer's demand.

### 1.1.4 Internal Organisational Factors

As the industrial sector is one of the significant sources of the environmental degradation and ecological impact (Amaranti et al., 2019; Solaja et al., 2020; C.-H. Wang, 2019; C. Wang et al., 2020; Yang et al., 2019; Zameer et al., 2020), the enhancement of its internal organisational functions can serve as a great mediator in order to reduce its impacts. Moving on to the effect of internal organisational factors, which include green dynamic capability and

organisational green culture, improves the manufacturing SMEs ability to survive in a competitive and dynamic green market.

Green dynamic capability includes responding to the evolving environmental regulations, developing green technology, and integrating environmental management into the organisation's entire strategy to achieve long-term competitiveness in manufacturing SMEs (Yacob et al., 2022). They can incorporate environmental factors into their innovations, strategies, and operational processes. This includes actions like deploying energy-efficient technologies, establishing sustainable supply chains, promoting environmental stewardship, and adopting cleaner industrial techniques (Palareti et al., 2016; S. K. Singh & El-Kassar, 2019; Tseng et al., 2019; C. Wang et al., 2020). According to the World Economic Forum (2019), zero waste to landfill is possible using the 5R approach which includes, repair, reuse, refurbish, re-manufacture, and recycle. Furthermore, they added that Schneider (also known as Schneider Electric Malaysia) has committed to recover its industrial waste of their 200 manufacturing sites 100% by 2030. In terms of Malaysia, the adoption rate of environmental friendly practices in manufacturing SMEs is quite slower, that is only 30% (Shahzad et al., 2023). This is due to the less knowledge about environmental friendly practices among manufacturing SMEs as compared to the large enterprises in Malaysia (Yacob et al., 2022). Furthermore, the authors added that many manufacturing SMEs managers and owners have less ideas regarding implementing sustainable measures. This could be achieved by following governmental regulations and societal norms and by integrating their

internal dynamic capabilities in order to be more competitive in a sustainable market.

Likewise, the organisational green culture within an organisation that supports environmental responsibility and sustainability (S. Wang et al., 2022) around the globe is one of the major contributors to the sustainable environment. This culture of innovation promotes the development of environmentally friendly goods and processes, providing businesses with a competitive edge in the green market (Zameer et al., 2020). Additionally, a strong green culture encourages a supportive atmosphere for employees and enhances their feelings to participate in green activities actively in order to deploy green innovation (Pan et al., 2022). This green culture awareness results in improved materials processing systems and an innovative green environment. The World Economic Forum (2019) represents a case of wheat straw packaging that helps to save 40% of energy and 90% of water reduction in the production process. This is achieved due to the healthy green culture within the organisations. However, in Malaysia, very little attention has been paid to the organisational green culture in manufacturing firms (Imran et al., 2021), due to which employees with a lack of knowledge and ideas related to the development of environmental friendly measures are unable to implement those initiatives. This could be one of the primary reasons for the dwindled ranking of Malaysia in the ecological sustainability index (Global Innovation Index, 2022).

To sum up, internal organisational factors like green dynamic capability and organisational green culture emphasise the growing concern about adopting

green innovations in the manufacturing SMEs. However, they encounter numerous challenges while adopting green innovation. This research aims to provide valuable insights for policymakers and businesses to foster a more sustainable and environmentally responsible manufacturing sector in Malaysia through the effective use of internal organisational culture and capabilities.

### 1.1.5 Big Data Analytics Capability

Organisations in many different industries are producing enormous amounts of data in the digital transformation age from various sources, including social media, gadgets, consumer interactions, and transaction logs (S. K. Singh & El-Kassar, 2019). Big data analytics capability helps organisations to analyse large and complicated datasets in order to discover hidden patterns, correlations, and trends to generate actionable insights that can improve operational efficiency, business process optimisation, strategic decision-making, and reduce environmental effects (Yu et al., 2022). It uses cutting-edge analytical approaches, including machine learning, data mining, and predictive modelling (Vassakis et al., 2018). It also entails developing opportunities and implementing sustainable solutions to address environmental issues like climate change, resource depletion, pollution, and biodiversity loss through data-driven solutions (Yu et al., 2022). According to the McCain (2023), the global big data market is worth more than $56 billion annually. The author added that 97.2% of businesses all over the globe are investing in big data, and on average more than 35% are analysing their data with the help of big data analytics capability. Approximately 10% of the costs are reduced due to the use of big data analytics.

Similarly, the government of Malaysia supports the implementation of big data analytics through the Malaysian Communications and Multimedia Commission (MCMC) in collaboration with the Malaysian Administrative Modernisation and Management Planning Unit and Malaysia Digital Economy Corporation (MDEC). Malaysia's big data analytics market is anticipated to expand from US$1.1 billion in 2021 to US$1.9 billion by 2025 (Malaysia Digital Economy Corporation [MDEC], 2021). Even though big data is gaining attention due to its critical importance and implications, only a small number of firms have implemented it and gained adequate value (Lutfi et al., 2022). Considering the fact that manufacturing SMEs in Malaysia are important contributors to the national economy, they are slow in big data analytics capability and implementation because of limited resources, financial constraints, and a lack of technical capabilities (Baig et al., 2023). However, big data analytics capability not only ensures valuable insights for the manufacturing SMEs but also helps them to implement sustainable measures through data-driven strategies (S. K. Singh & El-Kassar, 2019), so there is a need to ensure the implementation of big data analytics among manufacturing SMEs in Malaysia.

To conclude, big data analytics capability plays a crucial role in enhancing the adoption of green innovation in manufacturing SMEs by enabling data-driven decision-making and optimising sustainability efforts. However, leveraging big data for environmental initiatives presents challenges, including technological limitations and resource constraints. This research aims to offer valuable insights for policymakers and businesses on utilising big data analytics

effectively to drive sustainable practices and improve environmental performance in Malaysia's manufacturing sector.

## 1.2 Problem Statement

Based on the Global Innovation Index (2024) report, Malaysia ranks 33rd out of 133 countries, indicating room for improvement to reach the top 30. The report evaluates various indicators, including the institutional environment, ecological sustainability, environmental certifications, and innovation. Apart from that, the target to reduce 45% of greenhouse gas emissions by 2030 seems far to achieve since Malaysia's ranking has also noticed a fall to 86th rank in the ecological sustainability index (Global Innovation Index, 2024), which was 66th in 2022 (Global Innovation Index, 2022). This seems to be due to the worse performance in the low-carbon energy use index, now ranked 96th place compared to the replaced indicator of the environmental performance index ranked 62nd position in 2020 (Global Innovation Index, 2020). Moreover, as one of the major players contributing to Malaysia's economy, manufacturing SMEs still lag behind in adopting green innovation (Yu et al., 2022). According to the sustainability report for SMEs, only 43% of SMEs promote innovation in order to implement environmental friendly practices (Alliance Bank, 2025). Therefore, it was worthwhile to investigate external and internal factors that impact manufacturing SMEs to adopt green innovation. As manufacturing SMEs operate in a dynamic environment where both internal competencies and external conditions interact to shape strategic decisions (Mat et al., 2025), neglecting either dimension would result in an incomplete understanding of the

factors impacting green innovation adoption. Moreover, examining the moderating effect of big data analytic further enhances insights into manufacturing SMEs that can leverage data-driven decision-making to optimise eco-friendly practices (Loh & Teoh, 2021).

Private and government institutions have organised seminars, conferences, and campaigns on sustainable environment issues. For instance, Yayasan Hijau Malaysia (YHM) carries out many greening activities and programs, "Go Green" campaigns related to air, water and waste management. According to the Auditor-General's Report (2021), YHM had not fully achieved its objectives in promoting a green lifestyle. The report highlighted that YHM deviated from its original focus in six out of nine programs and only achieved 50% of its key performance indicator targets related to fundraising and operational expenditure (BERNAMA [Pertubuhan Berita Nasional Malaysia], 2022). Additionally, inefficiencies in program management led to RM990,000 in unutilised funds for the Green Guardian program and operating fee arrears amounting to RM3.31 million (BERNAMA, 2022). On the other hand, the MyHIJAU program consisting of an integrated attempt to improve and produce environmentally friendly goods and services in Malaysia has made notable progress. The MyHIJAU Mark program had approved 2,430 applications, covering 2,339 products and services from 567 companies. This initiative serves as Malaysia's official green recognition scheme, consolidating certified green products and services to facilitate green procurement (MGTC, 2022c). Despite these efforts, the adoption rate of these green innovations among manufacturing SMEs is still low (Yacob et al., 2022). Even with the enforcement of laws and

regulations such as the Environmental Quality Act of 1974, the Clean Air Legislation of 1978, and the Scheduled Wastes Regulations of 1989, manufacturing SMEs continue to become one of the major significant polluted industries with toxic and hazardous substances that seriously compromised the environment and human health (MGTC, 2022a). Hence, the study deserves to be investigated how the institutional environment influences manufacturing SMEs to adopt green innovation (Global Innovation Index, 2022).

Moreover, the pressure from customers becomes one of the major threats hindering manufacturing SMEs to adopt green innovation (Yousaf, 2021). Customers' green demand for the advantages of eco-friendly goods and practices has increased in Malaysia. In contrast, many consumers still place a higher value on affordability and convenience than sustainability, due to which the level of customer green demand seems to be relatively low in Malaysia compared to developed countries (Alganad et al., 2023). Additionally, many customers demand environmental friendly products in Malaysia, but in the case of extra prices for them should be low (Ahmad et al., 2023). In order to encounter customer green demand, manufacturing SMEs should implement green innovation, but the prices should be offered lower to them (Sun et al., 2024). Hence, it was worthwhile to study the impact of customer green demand on the adoption of green innovation in Malaysian manufacturing SMEs.

The manufacturing industry is experiencing difficulties in adopting green innovation and sustainable practices, especially among SMEs compared to large enterprises (Yu et al., 2022). Although environmentally friendly

manufacturing is urgently needed, manufacturing SMEs frequently face major challenges that limit their shift to green technologies and processes. These difficulties include a lack of understanding and adoption of green innovation among the manufacturing SMEs, which struggle to compete with large enterprises that often have more resources and technological capabilities to implement sustainable practices (Noranarttakun & Pharino, 2021a). There was an urgent need for a systematic strategy that can encourage SMEs to proactively adopt eco-friendly practices in order to overcome these barriers and promote the adoption of green innovation. However, the promotion and support for green competition activities remain insufficient due to the lesser attention paid within the organisations, which could otherwise serve as a catalyst for encouraging and driving green innovation adoption among manufacturing SMEs (Yu et al., 2022). Thus, there was a need to study the influence of green competition on the adoption of green innovation in manufacturing SMEs.

From a green dynamic capability perspective, the value produced by the Malaysian manufacturing SMEs is still low in the complex and dynamic business environment (Yacob et al., 2022). As the dynamic business environment changes towards technological adoption for environment sustainability, only 30% of the manufacturing SMEs in Malaysia were able to adopt it (Shahzad et al., 2023). This highlights that external support or environmental pressures alone are insufficient for widespread adoption. In other words, Malaysian businesses still struggle to maximise the benefits of their green product lines with current capabilities and resources. As a result, the enterprises' competitive advantages may not be long-term sustainable (Yu et al.,

2022). This limitation highlights the critical need for internal organisational mechanisms, such as green dynamic capabilities, to mediate the effects of the external environment on adopting green innovation. However, research on firms' green dynamic capabilities was primarily done in developed economies (S. K. Singh et al., 2022). Additionally, research on a firm's dynamic capabilities is rarely conducted in developing countries (Yousaf, 2021). Although the government of Malaysia has taken several initiatives for environmental friendly solutions, which include financing schemes, tax exemption, and green technology policy to support manufacturing SMEs in adopting green innovation. Still, the relationship between green innovation adoption and green dynamic capability among the developing nations like Malaysia is poorly understood, specifically in manufacturing SMEs (Yu et al., 2022). Therefore, an empirical study was required to advance our understanding of the mediating role of green dynamic capability between the external environments and the firm's capacity to adopt green innovation in manufacturing SMEs in Malaysia.

The company’s culture and strategic planning drive towards the adoption of green innovation (C.-H. Wang, 2019). The organisational green culture among Malaysian manufacturing SMEs faces several issues while adopting green innovation. One of the key issues is that when employees do not recognise the essential benefit of green innovation practices or they believe it is too costly to maintain green innovation, it becomes a hurdle for manufacturing SMEs (Noranarttakun & Pharino, 2021a). These internal challenges often hinder manufacturing SMEs from responding effectively to external pressures, despite growing environmental awareness and regulatory stimuli (Yacob et al.,

2019). Moreover, the implementation of a green organisational culture is still in its infancy among managers and owners of manufacturing SMEs in Malaysia (Subramanian & Suresh, 2023). Thus, it is insufficient to assume a direct connection between an external environment and green innovation adoption. Instead, organisational green culture should be conceptualised as a mediating mechanism that shapes the external conditions that influence innovation outcomes. Therefore, how organisational green culture mediates connection between external environment and green innovation adoption in manufacturing SMEs should be explored more.

Similarly, manufacturing SMEs confront significant barriers while utilising big data analytics capability in order to adopt green innovation (Yu et al., 2022). According to Shahzad et al. (2023), less than 21% of SMEs have implemented advanced technological initiatives in some production-related processes. One of the barriers includes a lack of dynamic capabilities such as resources, expertise, and skilled labour limits manufacturing SMEs' ability to use data analytics effectively for the adoption of green innovation (Yu et al., 2022). In addition, organisational culture plays a crucial role in the adoption process. However, a limited amount of Malaysian manufacturing SMEs utilise big data analytics, primarily due to a lack of cultural support for environmentally friendly practices (Shahzad et al., 2023). This lack of cultural support, combined with resource constraints, limits the ability of SMEs to fully utilise data analytics for enhancing their green innovation initiatives (Loh & Teoh, 2021; Yu et al., 2022). These challenges hinder SMEs from improving their environmental sustainability, operational efficiency, and competitiveness

in an increasingly eco-conscious market (Mubarak et al., 2021). However, it is important to note that big data analytics capability can potentially strengthen dynamic capabilities and foster an organisational green culture, thereby improving SMEs' overall efficiency and facilitating the adoption of green innovation. Therefore, the moderating effect of big data analytics on the internal organisational factors and manufacturing SMEs' adoption of green innovation needs to be examined.

Empirical research has identified key factors influencing green innovation practices in either SMEs or manufacturing firms (H. Li, 2022; Yousaf, 2021). These studies highlight the role of internal capabilities in shaping firms' sustainability practices (C.-H. Wang, 2019). In contrast, less collaborative research has been found that applies the institutional theory, which includes institutional and market environment pressures, and organisational cultural theory, which examines individual beliefs, behaviours, and values that specifically support green innovation adoption in Malaysian manufacturing SMEs. Moreover, limited studies have been found that focus on green innovation adoption (da Silva et al., 2023; Yu et al., 2022), whereas several studies have primarily examined green innovation practices (Bakarim et al., 2024; Z. Chen & Liang, 2023; Jassim & Challoob, 2021; Jayaraman et al., 2023; Khan et al., 2022; H. Li, 2022; H. Wang et al., 2021). Studying green innovation adoption is about integrating new eco-friendly solutions and driving broader positive impacts, while green innovation practices involve everyday environmentally responsible actions. Both are important, but green innovation adoption leads to systemic change and innovation (Jun et al., 2021).

The insufficient understanding of the combined effects of organisational green culture and green dynamic capabilities with the help of big data analytics capabilities is one of the potential study gaps in the context of green innovation adoption in Malaysian manufacturing SMEs. In contrast, past studies have looked into their effects on green innovation separately. Like, Yousaf (2021) investigated the effect of green dynamic capabilities, and Roespinoedji et al. (2019) studied organisational green culture's effect on green innovation. However, fewer investigations have been found on these factors collectively that support green innovation adoption among Malaysian manufacturing SMEs. In particular, a study examining the moderating influence of big data analytics capabilities on the connection between green dynamic capabilities and adopting green innovation, along with the relation between organisational green culture and green innovation adoption, was still required.

To address these issues mentioned above, institutional theory, organisational cultural theory, and dynamic capability theory were employed. Yu et al. (2022) investigated the impact of dynamic capability on green innovation adoption in manufacturing SMEs moderated by big data analytics capability. On the contrary, Razali and Jamil (2023) examined the influence of organisational culture on sustainability learning through the qualitative research. Nevertheless, it was still uncertain that manufacturing SMEs are enforced by institutional and market environments towards green innovation adoption mediated by internal organisational factors and moderated by big data analytics capability. However, this study also addresses manufacturing SMEs

aiming to improve their capabilities, culture, and sustainability goals through the adoption of green innovation. This study may direct the creation of strategies and interventions that foster green innovation and competitiveness in the context of manufacturing SMEs by utilising the synergistic benefits of green dynamic capability, organisational green culture, and big data analytics. Therefore, this study aims to enhance the understanding of this research area by exploring institutional environment and market environment that influence manufacturing SMEs to adopt green innovation mediated by internal organisational factors and moderated by big data analytics capability.

## 1.3 Research Objectives

The research project's main objective is to examine the adoption of green innovation in Malaysian manufacturing SMEs. The specific goals are:

- To examine the association between the institutional environment (formal institutions and informal institutions) and the adoption of green innovation in manufacturing SMEs.
- To examine the association between the market environment (customer green demand and green competition) and the adoption of green innovation in manufacturing SMEs.
- To investigate the mediating impact of internal organisational factors (green dynamic capability and organisational green culture) on the association between institutional and market environment towards adoption of green innovation in manufacturing SMEs.

- To examine the connection between internal organisational factors (green dynamic capability and organisational green culture) and the adoption of green innovation in manufacturing SMEs moderated by the big data analytic capability.

## 1.4 Research Questions

This research highlights the issues encountered in the green innovation adoption by answering the following questions:

- What is the association between the institutional environment (formal institutions and informal institutions) and the adoption of green innovation in manufacturing SMEs?
- What is the association between the market environment (customer green demand and green competition) and the adoption of green innovation in manufacturing SMEs?
- Is the association between institutional and market environment and green innovation adoption among manufacturing SMEs mediated by internal organisational factors (green dynamic capability and organisational green culture)?
- Does big data analytics capability moderate a connection between internal organisational factors (green dynamic capabilities and organisational green culture) and green innovation adoption in manufacturing SMEs?

## 1.5 Significance of the Study

### 1.5.1 Practical Significance

The practical significance of this study is that it will provide valuable information to policymakers and other stakeholders so they may enhance, monitor, cut costs, and effectively manage the adoption processes of green innovations to improve their manufacturing SMEs' performance and contribute towards a greener world.

Currently, Malaysia has been making notable strides in promoting sustainability and green adoption. Malaysia has implemented several initiatives, such as Malaysia's Green Technology Master Plan and National Policy on Climate Change, aimed at reducing carbon emissions, promoting renewable energy, and advancing green practices in the industrial sector. Furthermore, Malaysia is pushing for the integration of Industry 4.0 technologies in manufacturing, which presents an opportunity to embed green innovation into smart manufacturing processes. Despite these efforts, the pace of green innovation adoption among manufacturing SMEs remains slow, particularly in terms of utilising advanced technologies like big data analytics (Yu et al., 2022).

This investigation will serve as a reference to Malaysian manufacturing SMEs for disseminating information and knowledge related to the adoption of green innovation. Furthermore, it will also assist manufacturing SMEs in raising their level of green adoption in order to meet customer demand and compete in a green market, which results in more job creation, advancements in technology,

and green products that align with global sustainability goals. The insights gained from this research can also aid in reducing operational costs, increasing efficiency, and enhancing the competitiveness of manufacturing SMEs in the green market. Moreover, this study will also reveal the importance of big data analytics that can empower organisations to make data-driven decisions, leading to more effective and strategic implementation of green innovations. It can help not only manufacturing SMEs as well as large enterprises and other sectors to identify patterns and opportunities for sustainable practices, thereby enhancing their ability to adopt and succeed in green innovation.

### 1.5.2 Theoretical Significance

One of the important academic significances of this study is that most researchers emphasise green innovation practices (Z. Chen & Liang, 2023; H. Li, 2022; Yuan & Cao, 2022). However, this study will focus on green innovation adoption, which has greater theoretical importance. While practices describe what firms do on a daily basis, adoption captures the strategic decision-making and institutionalisation of eco-innovations within organisations. This shift is theoretically significant because it bridges the gap between intention and implementation, highlighting the conditions under which firms move from experimenting with eco-friendly practices to systematically embedding them. Moreover, studying adoption enables the integration of multiple theoretical perspectives such as, institutional theory, organisational cultural theory, and dynamic capability theory, offering a more comprehensive explanation of how external pressures and internal organisational factors collectively shape

sustainable transformation among manufacturing SMEs. As in recent years, past studies have explored limited insights into how different external and internal factors collectively influence green innovation adoption (da Silva et al., 2023; Yu et al., 2022). Z. Chen and Liang (2023) have studied institutional and market environments with respect to the green innovation. In contrast, Yu et al. (2022) examined the effect of green dynamic capability on green innovation moderated by big data analytics. Likewise, Pan et al. (2022) investigated the mediated role of organisational green culture on the relationship between green values, beliefs and feelings, and environment and society. The current study will highlight the role of the adoption of green innovation in manufacturing SMEs (Yu et al., 2022) moderated by big data analytics capability (C. Wang et al., 2020) and mediated by internal organisational factors such as green dynamic capabilities (S. K. Singh et al., 2022) and organisational green culture (Pan et al., 2022).

In terms of theoretical contribution, previous research presents solid justifications that firms should practice green innovation and the government should promote environmentally friendly adoptions (Z. Chen & Liang, 2023; Z. Huang & Xiao, 2023; X. Lin & Su, 2024). However, this study extends the existing literature by integrating institutional theory, organisational cultural theory, and dynamic capability theory to explain how external environment pressures, internal organisational factors, and big data analytics capabilities collectively influence the fostering of green innovation adoption in manufacturing SMEs. Various theories are typically used by different scholars studying green innovation practices. Among these theories, resource-based views (Z. Chen & Liang, 2023; H. Li, 2022; C.-H. Wang, 2019; Waqas et al.,

2021; Yuan & Cao, 2022) and planned behaviour theory (Tian et al., 2022; Yousaf, 2021) were frequently used in those studies. This study will serve as a reference in literature with the combination of institutional theory, organisational cultural theory, and dynamic capability theory in order to find the adoption of green innovation among manufacturing SMEs in Malaysia. This theoretical integration offers a multi-level perspective, where isomorphic pressures shape manufacturing SMEs' sustainability commitments, organisational culture mediates these external influences, and dynamic capabilities enable manufacturing SMEs to effectively adopt green innovation.

Additionally, this study will serve as a reference for other academicians to extend their knowledge and do further research on green innovation, particularly in Malaysia, where little research has been done on green innovation adoption in manufacturing SMEs. This study will serve as a resource for other researchers on issues related to literature reviews, methodology, and the expansion of green innovation adoption and manufacturing SMEs.

## 1.6 Scope of the Study

This study examines the adoption of green innovation among manufacturing SMEs in Malaysia by studying the institutional and the market environment's current practices and policies. It also delves into internal organisational factors that are integral to the process. These factors include the green dynamic capability, organisational green culture, and big data analytics capability. This study also includes determining the effects that hinder green

innovation adoption and suggesting different solutions to use their capabilities more efficiently. In addition to this, the focus of this study was on Malaysian manufacturing SMEs only.

## 1.7 Definition of Terms

The definitions of the terminologies used in this study are as follows:

Institutional environment: The institutional environment comprises of a combination of rules, traditions, and commonly accepted norms that exist within states, societies, professions, and organisations. These elements significantly influence the behaviour and outcomes of organisations, shaping how they operate and make decisions (Swaminathan & Wade, 2017).

Formal institutions: Formal institutions are those that formulate and enforce rules, regulations, policies, agreements, and governmental structures (Kaufmann et al., 2018).

Informal institutions: Informal institutions consist of strong environmental values, norms, and beliefs from multiple stakeholders, including consumers, employees, partners, competitors, and the media, within a society (M. Zhou et al., 2021).

Market environment: The phrase "market environment" refers to the external environment components that exert forces on a company and influence the performance of a market in some way (Tatum, 2023).

Customer green demand: It refers to customers' demand for environmentally friendly products (Z. Chen & Liang, 2023).

Green competition: Green competition is a unique competition that revolves around the ecological aspects of a company's strategies. It entails promoting goods and services that align with environmentally friendly practices and aims to achieve a competitive edge in the market (Hernández-Sánchez et al., 2020).

Green dynamic capability: Green dynamic capabilities are described as the organisation's capacity to renew and develop green organisational capabilities using internal and external resources and knowledge (Amaranti et al., 2019).

Organisational green culture: Green culture is a belief concept that most people in organisations share towards an environmentally friendly way of (co)production (X. Liu & Lin, 2020).

Big data analytic capability: Big data analytics capabilities are the organisation's capacity that enables them to collect and analyse data

proficiently, generating valuable insights and knowledge for better decision-making. (Mikalef et al., 2020).

Green innovation: The development and use of innovative technologies that reduce environmental risk, pollution, and other adverse effects of resource use (including energy use) compared to relevant alternatives (Castellacci & Lie, 2017).

Green innovation adoption: The process of adopting and implementing green technologies, products, and processes to reduce environmental impact (da Silva et al., 2023).

## 1.8 Chapter Organisation

Below is a summary of how the chapters are organised:

Chapter 1 includes a background of the study, problem statement, research objectives, research questions, the significance of the study, the scope of the study, the definition of terms, chapter organisation, and chapter summary.

In Chapter 2, the literature review is provided, which explores the underlying theories relevant to the research topic. This is followed by the development of hypotheses and establishment of the research model.

Chapter 3 commences with an overview of the research philosophy. It further discusses research design, sampling technique, data collection methods, and approach to data analysis.

Chapter 4 is offered to the presentation of the results of the analysis. It includes discussions on quantitative descriptions, the model measurement evaluation, and the structural model's assessment and will conclude with a summary of the obtained results.

Chapter 5 focuses on interpreting the findings related to the hypotheses and highlights the key implications. It also addresses any research limitations, provides recommendations for future studies, and concludes the thesis.

## 1.9 Chapter Summary

Chapter 1 introduces the research study. It provides an overview of the study's goals and questions while highlighting the importance of examining how these aspects interact. The chapter emphasises the study's scholarly, practical, and policy implications to advance sustainable manufacturing development. To improve sustainability practices, resource efficiency, and competitive advantage in manufacturing SMEs, the research aims to provide insights that may be gained by comprehending the function of green dynamic capability, organisational green culture, and big data analytics.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Overview

This chapter gives extensive background knowledge on the topics covered in this study. It includes the earlier theoretical work on green dynamic capability, organisational green culture, big data analytics, and green innovation in manufacturing SMEs. Additionally, this chapter discusses empirical review, conceptual framework, hypothesis development, and chapter summary.

## 2.2 Theoretical Review

In the discipline of organisational studies, it is essential for an organisation's long-term performance and sustainability to comprehend the dynamics that influence the organisation's conduct, structure, and capabilities (Yu et al., 2022). Institutional theory, organisational cultural theory, and dynamic capability theory are three well-known theories that provide essential insights into various aspects of organisational functioning. The institutional theory looks at how organisations tend to become more environmentally friendly in their practices and structures due to isomorphic pressures from external forces which comprises of coercive, mimetic, and normative pressure. The role of culture in influencing a firm's beliefs, norms, and values, as well as its ability to make decisions and overall performance in terms of the

environment, is explored in organisational cultural theory. On the other hand, dynamic capability theory examines how firms may respond and adapt to the constantly shifting business environment to obtain a competitive edge.

### 2.2.1 Institutional Theory

Institutional theory was developed by Meyer and Rowan in 1977. The theory was developed to explain why organisations tend to become similar to each other over time. The theory gained popularity in the 1980s and 1990s as researchers began to explore the role of isomorphic pressures in shaping organisational behaviour and practices. The theory gained prominence through DiMaggio and Powell (1983), who conceptualised three mechanisms of institutional isomorphism, coercive, mimetic, and normative pressures, that shape organisational behaviour and practices. Since then, institutional theory has been widely applied to understand how external environments influence organisational conformity, legitimacy, and strategic decision-making (Ashworth et al., 2007; Masocha & Fatoki, 2018; Verbruggen et al., 2011).

It is a theoretical framework that aids in explaining the adoption of eco-innovation methods for SMEs. In addition to being a successful approach for dealing with environmental regulatory pressure, green innovation is a crucial way to raise the productivity of all factors by efficiently using resources and energy (Yuan & Cao, 2022). Institutional theory suggests that organisations are under pressure from external sources to adhere to particular behaviours, which leads to the isomorphic replication of these practices across many

organisations (Ashworth et al., 2007; DiMaggio & Powell, 1983). According to the institutional theory (DiMaggio & Powell, 1983; Lewis et al., 2019), organisations embrace green innovation techniques due to external pressure which includes coercive, mimetic, and normative pressures.

Coercive pressure arises from formal and informal institutional forces that compel organisations to conform to rules, standards, norms, and societal expectations to maintain legitimacy (Sarkis et al., 2011). In this study, coercive pressure reflects the institutional environment which comprises of formal and informal institutions, due to the pressure of regulatory bodies (Sarkis et al., 2011; Yuan & Cao, 2022) that enforce compliance with sustainability objectives. For example, governments impose environmental laws, sanctions, and emission limits to ensure industrial compliance (Gurlek, 2023; J. Zhou et al., 2021). In Malaysia, coercive pressures are evident in initiatives such as green tax, subsidies, and carbon trading frameworks, which reduce SMEs' upfront costs and encourage the implementation of green innovation (Latip et al., 2022; Masocha & Fatoki, 2018). At the same time, informal institutions exert coercive influence through community expectations, social approval, and moral obligations toward sustainability (Yuan & Cao, 2022). Together, these formal and informal institutions represent the coercive environment that pushes SMEs to adopt green innovation to maintain legitimacy and social acceptance.

Secondly, normative isomorphism refers to acting professionally correctly due to the customer's (Gurlek, 2023) green demand. In this study, customer green demand represents the normative pressure that motivates SMEs

to align their production and product strategies with customers' environmental preferences. As environmental awareness grows, customers increasingly expect sustainable and eco-friendly products (Gurlek, 2023; Thomas et al., 2021). This expectation acts as a normative influence, encouraging firms to adopt green innovations to meet stakeholder values and maintain reputation (Thomas et al., 2021). For manufacturing SMEs, fulfilling these customer-driven normative pressures helps build trust, loyalty, and legitimacy in an environmentally conscious market.

Lastly, mimetic isomorphism is the green competition that helps organisations to copy legitimated and/or prosperous counterparts in their business (Y. Chen et al., 2024; Justin & Obara, 2019). In this study, green competition represents mimetic pressure, as SMEs emulate the environmental strategies of competitors who are perceived as successful or legitimate. When rival firms gain competitive advantages by implementing green innovations such as waste reduction, energy efficiency, or eco-friendly technologies others manufacturing SMEs tend to replicate these strategies to maintain market competitiveness and legitimacy (Caldera et al., 2019). Thus, mimetic pressure encourages the diffusion of green innovation practices across the industry, fostering a collective movement toward sustainability (Y. Chen et al., 2024).

Manufacturing SMEs looking to implement green innovation strategies must fully comprehend the impact of isomorphic pressure. By acknowledging the role of coercive forces, organisations can proactively follow environmental standards and avert possible legal consequences (Z. Chen & Liang, 2023).

Normative pressures highlight the need to match corporate practices with social norms (Altayar, 2018; Lewis et al., 2019), which will strengthen stakeholder relationships and reputation. Mimetic pressures give firms access to information on industry best practices, enabling them to learn from successful peers and implement successful green innovation methods (Yuan & Cao, 2022).

The institutional theory sheds light on the motivations driving green innovation adoption techniques in manufacturing SMEs. Coercive, normative, and mimetic forces influence organisational decisions (Lewis et al., 2019) to adopt green innovation. It highlights how these pressures can effectively support SMEs' transition toward green innovation. By comprehending these forces, organisations can strategically align their activities with environmental sustainability goals and achieve a competitive edge in the market.

### 2.2.2 Organisational Cultural Theory

Organisational cultural theory provides a foundation for understanding how shared values, beliefs, and norms within an organisation shape employee behaviour, decision-making, and strategic outcomes (Hatch, 1993; Schein, 1983). The roots of organisational culture research trace back to the 1940s when anthropologists and folklore scholars began exploring work traditions and social norms (Meek, 1988). However, the concept gained academic prominence in the 1980s and 1990s through the work of Schein (1983, 1990, 2010), who emphasised that organisational culture profoundly influences strategic implementation and employee actions.

Although, an organisation's green culture is the one that is least likely to alter. Schein (2010) identified three layers of culture, including artifacts, espoused beliefs and values, and underlying assumptions that helps in building and developing a green culture within an organisation. First, artifacts can be seen, heard, and felt by anybody who comes into contact with the organisation's desires regarding environmental friendly operations (X. Liu & Lin, 2020). This could be achieved by making sustainability tangible and communicating a commitment to environmentally friendly practices. The second layer consists of espoused beliefs and values, which are those that are held by the organisation's founders or strong managers and can offer the group a feeling of what sustainable practices should be followed (Nunhes et al., 2020). When a company's values prioritise environmental sustainability, it fosters a culture that aligns with green goals, encourages collective commitment, ethical decision-making, innovation, and responds to stakeholder expectations, ultimately driving towards the green innovation adoption. "Underlying assumptions" are the repeatedly applied sustainable solutions for environmental issues that have come to be accepted as fact and are believed to be the organisation's routine of operation by the group (Pichlak & Szromek, 2022). When sustainability is deeply ingrained in these assumptions, it creates a culture where sustainable practices are second nature, resilient to change, and holistically integrated throughout the organisation.

According to Schein (2010), a culture's functional effectiveness and perceived goodness depend not only on the culture itself but also on how it

interacts with the environment. Hofstede (1980) broadened the definition of culture beyond the nation to include other collective entities such as families, professions, and organisations. He pointed out that once an organisation builds a history, that history constrains its behaviour. Smircich (1983) identified an essential question: "What exactly does a 'cultural perspective' on an organisation mean?" She defined the point where organisational theory and anthropology converge in an effort to provide an explanation. She highlighted five themes in management and organisation, including corporate culture, cognitive organisation, organisational symbols, processes unconsciousness and organisation, and cross-cultural or comparative management. Denison and Mishra (1989) investigated the relationship between "organisational culture" and "organisational effectiveness." In that study, four hypotheses were put forth on the benefits of the four characteristics of organisational culture involvement, consistency, adaptability, and mission on organisational effectiveness. They established the validity of all four hypotheses and demonstrated that all cultural characteristics will enhance an organisation's effectiveness. They also concluded that the most important indicator of effectiveness is the mission.

Organisational culture thus functions as a guiding framework that determines how companies interpret and respond to environmental challenges (Akpa et al., 2021; Grennan & Li, 2023). Such cultures imply shared values, conventions, and beliefs dictating companies' decision-making processes and operations (Grennan & Li, 2023) towards the implementation of sustainable solutions. Organisational culture is crucial in the context of green innovation for encouraging environmental friendly activities inside manufacturing SMEs. This

has made it pivotal for manufacturers to promote environmentally workable practices amongst their employees through strategically generating such activities' necessary efforts while fostering innovation (Chang, 2020).

#### 2.2.2.1 Organisational Green Culture

Within the broader organisational cultural theory, organisational green culture is conceptualised as the manifestation of environmental values, norms, and beliefs shared by members of an organisation (Sarkis & Zhu, 2018; Vargas-Hernández et al., 2024). It reflects how deeply sustainability principles are embedded within an organisation's cultural system and how they influence strategic and operational behaviours (Y.-S. Chen & Chang, 2013; Yu et al., 2022).

Subramanian and Suresh's (2023) research points out that a strong organisational green culture promotes an internal environment where environmentally sustainable activities are prioritised and supported through shared understanding and commitment in SMEs. When firms establish such a culture, employees develop intrinsic motivation to engage in eco-innovative behaviour and adopt environmentally friendly solutions. Similarly, in a different study, Salvioni and Almici (2020) also examined how organisational culture influences green innovation in the manufacturing sector. The study concentrated on the idea of a "circular economy" and how it relates to the organisational green culture. According to the research, companies with a strong collaborative green

culture, an openness to change, and a long-term focus were more likely to adopt circular economy concepts and participate in green innovation.

Pan et al. (2022) also investigate the impact of organisational green culture on organisational development and for the sake of society and the environment. The study concentrated on how cultural factors, including green feelings, social norms, and environmental values, affect adopting environmentally friendly solutions and achieving competitive advantage. The results showed that businesses could adopt and apply eco-innovations with a solid environmental friendly culture and encourage corporate social responsibility. The study stressed that organisational green culture has a role in influencing how likely organisations are to adopt green innovation.

Green values, beliefs, and feelings must be present to nurture and influence organisational culture, especially in the development of green culture (Pan et al., 2022). Employee attitudes and behaviours toward green innovation can significantly influence who firmly commits to sustainability and environmental stewardship (Mehak & Batcha, 2024).

Fang et al. (2022) study examined how social values affect the green culture. The study concentrated on how different philosophies, such as transformational leadership and green HRM may help advance environmental sustainability. According to the research, values demonstrating transformational leadership were more likely to foster an environment that prioritises ecological sustainability and promotes green behaviour. The study stressed the significance

of values in building a green culture and guiding organisational change toward environmental performance.

Similarly, Gadenne et al. (2009) investigated how belief affected environmental performance and green culture in Australian industrial businesses. The study concluded that strong green cultures were more likely to be established within firms by executives who actively communicated and showed a commitment to environmental principles and goals. Furthermore, having a strong green culture had a beneficial impact on environmentally responsible businesses.

In this study, organisational green culture serves as an internal organisational mechanism that mediates the relationship between external institutional and market pressures and green innovation adoption. From a theoretical perspective, this linkage is grounded in organisational cultural theory, which posits that cultural alignment translates external expectations into internalised organisational behaviours. A strong green culture enables SMEs to interpret regulatory, customer, and competitive pressures not as constraints but as opportunities for innovation and improvement.

Thus, organisational cultural theory underpins the role of organisational green culture in this research by explaining how shared environmental values and beliefs transform institutional and market pressures into concrete green innovation adoption.

### 2.2.3 Dynamic Capability Theory

The concept of dynamic capabilities was first introduced by Teece et al. in their article in 1997. The theory expands the traditional resource-based view by emphasising the dynamic nature of resources and the firm's ability to adapt its capabilities over time to maintain competitiveness. Teece et al. (1997) argue that dynamic capabilities enable organisations to transform short-term competencies into long-term advantages. In this study, dynamic capability theory addresses the ability of manufacturing SMEs to combine, establish, and reorganise their internal and external competencies to address environmental concerns with the help of green dynamic capabilities and big data analytics capabilities.

Teece (2007) identifies three main organisational capability clusters of dynamic capabilities that produce various activities in order to determine dynamic capabilities from the perspective of an organisation. Sensing, seizing, and reconfiguring capabilities are the three clusters. Sensing capability is the ability to identify environmental changes, risks, and opportunities in technological and market landscapes (S. K. Singh et al., 2022; Teece, 2010). Likewise, seizing capabilities is the ability to mobilise resources and make strategic decisions to exploit these opportunities (J.-W. Huang & Li, 2017). Lastly, reconfiguring capabilities is the ability to realign and renew its internal and external resources, structures, and processes in response to environmental challenges (J.-W. Huang & Li, 2017) on current capabilities (Waqas et al., 2021).

Organisations can develop dynamic capabilities that let them create an ecosystem around their operations where risks and opportunities can be recognised in the market by sensing, seizing, and reconfiguring capabilities (Cadden et al., 2023; S. K. Singh et al., 2022). The above capabilities are linked since sensing is required for seizing, and reorganising requires the capabilities to seize opportunities (Teece, 2007). Eisenhardt and Martin (2000) provide examples of dynamic capabilities such as routines for product development (such as resource integration and product innovations), strategic decision-making (such as directing and redirecting the business environment, human skills, and organisational structures), and resource reconfiguration (such as copying, transferring, and recombining resources within the organisation).

The difference in performance across organisations with identical resources in the same environment is due to varying green dynamic capabilities for detecting environmental changes and internalising resources from outside (Eisenhardt & Martin, 2000; Teece et al., 1997). For optimal green innovation performance, an organisation must not only have specific green resources and beneficial capabilities but also green organisational capabilities that can perceive the transforming market environment and utilise resources efficiently (Sun et al., 2024). Green dynamic capability are thus described as organisation-specific capabilities to recognise change opportunities, seize these opportunities, and rearrange resources to respond to these changes, particularly those including environmental concerns (Amaranti et al., 2022).

Building on dynamic capability theory, green dynamic capability is conceptualised as the firm's ability to integrate environmental considerations into the sensing, seizing, and reconfiguring processes (Amaranti et al., 2022; Zhang, Ouyang, et al., 2020). It represents the organisation's capacity to acquire, combine, and integrate resources for eco-innovation and environmental management (Teece, 2018). Firms with strong green dynamic capabilities can effectively: sense environmental opportunities and threats by scanning markets and regulatory landscapes for sustainability trends, seize opportunities by developing eco-innovative products and processes, and reconfigure resources by integrating sustainable technologies and operational practices (Qiu et al., 2020; Yuan & Cao, 2022).

Empirical studies confirm that green dynamic capaility enhances organisational adaptability, innovation speed, and environmental performance (H. Li, 2022; Sun et al., 2024). For example, Zhang, Ouyang, et al. (2020) found that integrating green production and business models significantly strengthens firms' environmental responsiveness. Similarly, M. Zhou et al. (2021) demonstrated that absorptive capacity is the ability to recognise, assimilate, and apply new environmental knowledge that plays a crucial role in developing green dynamic capability. This capacity enables firms to integrate specialised sustainability knowledge and align it with strategic objectives (S. Wang et al., 2022).

Green dynamic capability therefore extends the dynamic capability theory by embedding environmental orientation within the capability

framework, offering SMEs a mechanism to achieve both competitive and ecological advantage (Amaranti et al., 2022; Yu et al., 2022).

Furthermore, big data analytics is a powerful tool that can enhance the effectiveness of green dynamic capability in manufacturing SMEs. It can provide valuable insights and support decision-making processes by sensing and seizing opportunities related to green innovation adoption (Yu et al., 2022). Yu et al. (2022) find the positive moderating influence of big data analytics capabilities on the connection between green dynamic capabilities and the adoption of green innovation (Yu et al., 2022). This suggests that manufacturing SMEs with strong big data analytics capability are more likely to effectively leverage their green dynamic capabilities for adopting green innovations. The role of big data analytics capabilities also promotes competitive advantage in the manufacturing sector (Al-Khatib, 2022). The impact of big data analytics capabilities positively influences green supply chain performance, with green innovation mediating this relationship and strengthening by data-driven culture. This highlights the potential of big data analytics in driving sustainable practices along with performance in green supply chains.

In conclusion, the dynamic capability theory offers a valuable configuration for comprehending how green dynamic capabilities support green innovation and competitive edge (Z. Chen & Liang, 2023). The literature study emphasises the significance of dynamic capabilities, including identifying and capturing green opportunities, reallocating resources, changing environmental concerns, and using big data analytic capabilities. In order to support sustainable

manufacturing processes in SMEs, our findings will highlight the test relationship of environment-conscious capabilities and continuously adapting and learning toward green innovation that could be attained by sensing, seizing, and reconfiguring green organisational capabilities with the use of big data analytics capability.

### 2.2.4 Theoretical Integration

The institutional theory (DiMaggio & Powell, 1983; Lewis et al., 2019) explains that organisations adopt green innovation due to external pressures, which can be categorised into coercive, mimetic, and normative pressures. Coercive pressure arises from the regulatory environment, where firms comply with formal and informal institutional requirements to maintain legitimacy (Sarkis et al., 2011; Yuan & Cao, 2022). Mimetic pressure refers to firms imitating successful competitors' green practices, particularly in uncertain market conditions where proven sustainable strategies are copied to maintain competitiveness (Justin & Obara, 2019). Normative pressure is linked to professional standards and customer-driven sustainability demand, compelling firms to adopt environmentally friendly practices to align with industry norms (Yuan & Cao, 2022).

The organisational cultural theory highlights the role of organisational green culture in shaping firms' internal sustainability efforts. A strong green culture ensures that sustainability becomes an inherent part of business strategy and daily operations (X. Liu & Lin, 2020). This theory helps to explain the

potential for manufacturing SMEs to proactively embrace green innovation beyond external pressures. Organisational culture acts as a mediating factor that influences manufacturing SMEs in response to isomorphic pressures. When a firm has a deeply embedded green culture, it is more likely to integrate sustainable practices seamlessly (X. Liu & Lin, 2020) rather than merely reacting to external demands.

The dynamic capability theory provides insight into the internal competencies that enable firms to adapt to sustainability challenges (Waqas et al., 2021). Green dynamic capability refers to an organisation's ability to integrate, develop, and reconfigure its resources to drive green innovation (S. K. Singh et al., 2022). This involves monitoring environmental trends, absorbing new sustainability knowledge, and efficiently allocating resources toward green initiatives (Z. Chen & Liang, 2023). Additionally, big data analytics capability plays a crucial role in enhancing decision-making related to sustainability. By leveraging advanced data analytics, firms can assess environmental impacts, optimise resource usage, and identify new opportunities for green innovation (Waqas et al., 2021). This theory explains the internal capabilities to facilitate a firm's ability to respond effectively to external sustainability pressures (Yu et al., 2022).

Integrating these three theories provides a comprehensive perspective on green innovation adoption in Malaysian manufacturing SMEs. Institutional theory explains the role of manufacturing SMEs in adopting green innovation due to external pressures. Organisational cultural theory describes internal

beliefs, values, and culture that shape green innovation strategies in manufacturing SMEs. Dynamic capability theory highlights the internal capabilities, such as green dynamic capabilities and big data analytics capabilities, that enable manufacturing SMEs to adapt green innovation initiatives. This theoretical integration strengthens the study by bridging institutional, cultural, and capability-based perspectives, offering valuable insights for both academia and industry on fostering green innovation in manufacturing SMEs.

## 2.3 Empirical Review

### 2.3.1 Institutional Environment (Formal Institutions and Informal Institutions)

According to D. Li and Shen (2022), the institutional environment, which consists of both formal and informal institutions, has a considerable impact on how SMEs behave and make decisions. The government policies, frameworks of regulations, and industry standards are known to be formal institutions, whereas social networks and cultural norms are called informal institutions (Ji et al., 2019).

Formal institutions within the institutional environment are regulatory frameworks and regulations established by governments and industry organisations to ensure compliance with environmental standards (Ji et al., 2019). Government rules, for instance, may prescribe specific environmental performance parameters, including goals for reducing emissions or strategies to

handle the waste. Organisations may adhere to guidelines and benchmarks set by industry-specific standards and certifications like ISO 14001 (Environmental Management Systems) (Freire & Pieta, 2022; Shafique et al., 2017). By enforcing regulatory requirements and market pressures on SMEs to align their operations with environmentally sustainable approaches (Camarena-Gil et al., 2020). Prior studies have shown that regulatory frameworks establish structured guidelines that SMEs must follow to ensure environmental compliance, thereby fostering sustainable practices (Castro & Guzmán, 2019). Lu and Yu (2020) and X. Wang et al. (2022) empirical studies have demonstrated that stringent environmental regulations encourage firms to invest in green technologies, thereby increasing their sustainability performance (Camarena-Gil et al., 2020).

In contrast, informal institutions are social networks, shared values, and cultural norms that impact how people behave and organisations operate without legal enforcement (Ji et al., 2019). These include pressure from consumers, employees, business partners, and environmental groups to adopt sustainable practices (D. Li & Shen, 2022). The institutional environment of informal entities influences the organisational capabilities, culture, and values to sense, seize and reconfigure opportunities associated with sustainability. For instance, SMEs may adopt innovative decisions if they have a culture of environmental awareness and accountability (Baggia et al., 2019; Castro & Guzmán, 2019). Informal institutions may arise from a community's shared values, stakeholders' collaboration, spreading of knowledge, and best practices. Studies have found that social legitimacy plays a crucial role in influencing SMEs' sustainability strategies, with informal institutional forces such as public

awareness and social trust driving firms to adopt greener solutions (Baggia et al., 2019; Yang et al., 2021). Empirical research highlights that cultural expectations and stakeholder pressures often lead businesses to integrate environmentally responsible practices into their operations (Ji et al., 2019; D. Li & Shen, 2022).

According to J. Zhou et al. (2021), the institutional pressure, which includes both formal and informal institutions, affects the intensity and manner of environmental friendly innovations through its regulations and norms. Informal institutions contribute to the cultural and social background that pressurise environmentally friendly practices, while formal institutions put pressure through the legal and regulatory framework (Ji et al., 2019). Overall, both types of institutions correspond and affect organisational behaviour, establishing an atmosphere for green innovation (D. Li & Shen, 2022). However, in terms of Malaysian manufacturing SMEs, there is a need to investigate the correlation between formal and informal institutional environments and the green innovation adoption.

### 2.3.2 Market Environment (Customer Green Demand and Green Competition)

The market environment plays a pivotal role in shaping the strategies and performance of manufacturing SMEs, particularly in the context of sustainability. This empirical review examines the two key aspects of market

environment. It includes customer green demand and green competition in manufacturing SMEs (Z. Chen & Liang, 2023).

Customer green demand is a concept used to describe customers' increasing demand for products and services that are environmentally friendly (Dabija et al., 2018; Yu et al., 2022). Consumers are actively looking for items that reflect their values of sustainability, energy efficiency, and minimal environmental impact due to the increased awareness of environmental hazards (Chang, 2020; Y.-S. Chen & Chang, 2013). Prior empirical studies have measured customer green demand using surveys and sustainability reporting (Cai & Li, 2018). Research by Z. Chen and Liang (2023) highlights that customer green demand is typically assessed based on factors such as customer willingness to pay for green products, and market preference shifts toward sustainability. Likewise, Baggia et al. (2019) analysed how firms respond to consumer-driven sustainability by assessing green marketing efforts and product development strategies aligned with customer expectations.

Green competition refers to the market environment where firms differentiate themselves based on environmental efficiency and sustainable initiatives (Z. Chen & Liang, 2023). Manufacturing SMEs are pressured to show their commitment to sustainability and compete on ecological grounds as more businesses follow sustainable practices (Castro & Guzmán, 2019). Maniu et al. (2021) examined green competition in Romanian SMEs by assessing industry-wide sustainability efforts, corporate disclosures on green initiatives, and firm-level investments in eco-friendly technologies. Competitive pressure stimulates

firms to adopt and implement sustainable technology, processes, and products in order to obtain a competitive edge (Ceptureanu et al., 2020; Wirda et al., 2019). As demonstrated by S. K. Singh and El-Kassar (2019), Wirda et al. (2019), and Yu et al. (2022), green competition fosters innovation and continuous improvement procedures within manufacturing SMEs in order to compete in the industry. Moreover, the competitive pressure within the industry influences other manufacturing SMEs to develop a green image compared to competitors by adopting eco-friendly measures (Cai & Li, 2018).

By understanding customer green demand and green competition, manufacturing SMEs can align their strategies with evolving market expectations. Through the customer demand and competition within manufacturing SMEs, it could pressurise manufacturing SMEs to build a green image, fulfil customer requirements, and gain the competitive edge in the market. In the context of Malaysian manufacturing SMEs, these factors (customers green demand and green competition) must investigate their effect on the adoption of green innovation in order to prosper in rapidly changing environment of sustainable business (Z. Chen & Liang, 2023).

### 2.3.3 Internal Organisational Factors

Internal organisational factors play an important role while driving sustainability and environmental performance within an organisation. Two dimensions that have been chosen as key factors under internal organisational factors are green dynamic capability and organisational green culture. These

dimensions have been selected based on their significance in promoting sustainable practices and driving green innovation within manufacturing SMEs to address environmental concerns and achieve a competitive edge. Understanding the elements affecting green innovation within manufacturing SMEs has drawn more attention recently (Tajudeen et al., 2020). Z. Chen and Liang (2023) have discovered the internal factors that can affect green innovation within firms.

Green dynamic capability refers to an organisation's ability to sense, seize, and transform opportunities related to environmental sustainability (Yu et al., 2022). Yuan and Cao (2022) looked into the mediating role of green dynamic capability between the relationship of corporate social responsibility. They found that green dynamic capability affects the performance of green product and processes in Chinese manufacturing enterprises. As indicated in the research, businesses with more robust green dynamic capabilities performed more effectively in terms of production efficiency for green products and services (Jo & Kwon, 2022). According to the authors, incorporating environmental concerns into different organisational tasks, including R&D, production, and marketing, is essential for generating superior green outcomes (Meirun et al., 2020).

Prior studies have examined green dynamic capability by assessing a firm's capacity to integrate environmental knowledge into decision-making, allocate resources for green initiatives, and develop eco-friendly innovations (Yin et al., 2019; Yuan & Cao, 2022). It is typically measured through indicators

such as environmental knowledge absorption, green resource reconfiguration, and sustainability-driven innovation processes (Amaranti et al., 2022). This capability has been examined through various dimensions, including adaptive flexibility, collaboration with external sustainability stakeholders, and the incorporation of green technologies in operational frameworks (Ortiz-avram et al., 2024). Studies also suggest that green dynamic capability is assessed using firms' ability to enhance internal knowledge-sharing networks for sustainability-driven transformations (Y. Liu et al., 2020; Waqas et al., 2021; Zhang, Ouyang, et al., 2020). Furthermore, studies have highlighted that firms with strong green dynamic capabilities are more likely to implement proactive environmental management systems, enhance environmental learning capabilities, and sustain green product innovations (Tseng et al., 2019). SMEs that effectively integrate green dynamic capabilities also tend to foster open innovation ecosystems where sustainability-focused collaborations drive continuous environmental improvements (Bari et al., 2022).

X. Liu and Lin (2020) describe organisational green culture as the shared values, assumptions, and conventions that influence how people behave and think about the environment. It stands for the staff's overall engagement and dedication to environmental sustainability. Over the past five years, researchers have started recognising the value of organisational green cultures in supporting sustainability in manufacturing SMEs.

Moreover, the green organisational culture and the employee's responsible behaviour towards the environment and society in Pakistani

manufacturing and services businesses were examined in a study by Pan et al. (2022). The study examined how green organisational culture mediates the relationship between green values, beliefs, feelings, society, and the environment (S. Wang et al., 2022). In addition, the researchers have also focused on organisational culture and leadership commitment to environmental policies, employee engagement in sustainability initiatives, and the formal integration of green practices in corporate decision-making (Pan et al., 2022; S. Wang et al., 2022).

Similarly, Afum et al. (2020) investigated the green organisational culture mediation affected Ghana manufacturing companies' capacity for environmental performance. They showed that environmental management practices like green manufacturing practices and green procurement result in improved environmental performance through prioritising long-term environmental responsibility. The authors stressed that green procurement (Bucea-Manea-Toniş et al., 2021; Dabija et al., 2018; He et al., 2018) and innovative green manufacturing techniques for environmental preservation are crucial for implementing creative green ideas within manufacturing firms (Joshi & Dhar, 2020; Y. Li et al., 2023).

In conclusion, these components promote employee involvement, enable proactive responses to environmental concerns, create value, and offer essential insights for decision-making. They work together to create a future that is greener and more sustainable (Yousaf, 2021). As supported by the above studies, green dynamic capabilities and organisational green culture have a

relationship with the green innovation. It is needed to study these internal organisational factors in Malaysian manufacturing SMEs.

### 2.3.4 Big Data Analytics Capability

Big data analytics capability refers to an organisation's capability to effectively collect, analyse, and utilise vast amounts of data to obtain insights and make informed decisions (Dai & Liang, 2022; Tian et al., 2022). In the context of sustainability, big data analytics capability has been recognised as a key enabler of environmental management by allowing firms to monitor ecological impacts, optimise resource utilisation, and support green innovation initiatives (Yu et al., 2022).

Empirical research has used big data analytics capability through several dimensions, including data infrastructure, analytical skills, and decision-making effectiveness (L. Wang et al., 2022). Waqas et al. (2021) and Z. Chen and Liang (2023) suggest that firms with high big data analytics capabilities possess advanced technologies for data collection and analysis, integrate diverse data sources for sustainability insights, and apply sophisticated visualisation and predictive modelling techniques to support environmental strategies. Additionally, big data analytics capability is assessed based on an organisation’s ability to leverage green human resource management practices for real-time environmental monitoring and policy compliance (Mahmood et al., 2023).

Moreover, Mikalef et al. (2019) highlighted that organisations with strong big data analytics capabilities demonstrate a greater ability to integrate data-driven insights into strategic planning, enhancing their responsiveness to environmental regulations and market shifts. Z. Chen and Liang (2023) and Yu et al. (2022) research suggests that big data analytics capability is measured through firms' ability to process large-scale sustainability data efficiently and translate it into actionable environmental strategies. SMEs can improve their competitiveness by using big data analytics techniques to gain insightful information about environmental trends, consumer preferences, and operational inefficiencies (Yu et al., 2022).

In short, the studies mentioned above demonstrate that big data analytics capabilities are critical in boosting the impact of organisational and environmental performance. Organisations may unleash the potential of their internal resources and cultures by utilising advanced analytics approaches, resulting in more successful and focused green initiatives (Z. Chen & Liang, 2023).

### 2.3.5 Green Innovation Adoption

Green innovation refers to the actions taken by organisations to ensure their organisational sustainability through innovation that will cut costs, speed up delivery, make the best use of available resources, and protect the environment (Bucea-Manea-Toniş et al., 2021; Castro & Guzmán, 2019; Cicea et al., 2022). According to H. Wang et al. (2021) and Wirda et al. (2019), green

innovation is used in communicating, product designing, and streamlining work completion in all businesses' administrative, support, operational, and technical departments. As indicated by Y. Li et al. (2023), it is essential since one of the prominent industrial trends at the moment is the environmental self-regulatory strategy or the process of making the industry green.

However, the choice of the current study to focus on the adoption of green innovation rather than green innovation performance is based on several reasons. Firstly, green innovation adoption refers to the process of integrating and implementing environmentally friendly practices and technologies (Y.-S. Chen et al., 2006) within manufacturing SMEs in Malaysia, which can have significant implications for the organisation's environmental impact and sustainability efforts. Secondly, it allows researchers to understand the strategic implications and competitive advantages that manufacturing SMEs can gain from embracing sustainability, as it can lead to improved corporate advantage, increased market opportunities, and enhanced competitiveness (Arenhardt et al., 2016; Y.-S. Chen et al., 2006). Furthermore, it provides insights into the organisational processes and dynamics that allow researchers to detect the role of external pressures, internal organisational factors, and big data analytics in driving the adoption of green innovation (Y. Li et al., 2019) in Malaysian manufacturing SMEs. While green innovation performance is the crucial outcome of adopting eco-innovation practices, focusing solely on performance may overlook the complexities and challenges associated with the adoption process. By studying the adoption of green innovation, researchers can gain a deeper understanding of the factors that influence organisations' decision-

making processes, resource allocation, and implementation strategies (Pacheco et al., 2018). This knowledge can provide information or guidelines to policymakers, managers, and practitioners in developing effective strategies to promote the widespread adoption of green innovation and drive sustainable development in manufacturing SMEs.

The concepts of environmental management, like green management, green marketing, green production, and green innovation (Eksandy et al., 2021), as well as green intellectual capital (Ceptureanu et al., 2020), are now being pursued to address the issues of ecological pollution. The most typical acronym for advanced green capability, which is always associated with it, is "green technology" (Naway & Rahmat, 2019; Ramli et al., 2023; Shin et al., 2018; Yao et al., 2022). According to Z. Chen and Liang (2023), internal and external factors reduce environmental impact and improve green practices within an organisation. Internal drivers include lowering environmental expenses, improving water quality from wastewater treatment, resolving wastewater treatment issues in the cone paper process, and lowering employee turnover rates due to challenging working conditions (Guarini & Oreiro, 2022). The external drivers are to adhere to strict environmental laws and serve promptly in response to customer "green" demands, which also boosts "green" competitiveness for local and international markets (Z. Chen & Liang, 2023), which can be influenced by the organisation's culture as well.

To adapt to the "green" lifestyles human behaviours must change (Cheng et al., 2022; Dabija et al., 2018). When it comes to lowering carbon

emissions, waste, air pollution, and environmental effects, people must alter their behaviour in multiple ways, a few of which cannot be recognised until they have a deeper understanding of green technology (Gao et al., 2022; Hong et al., 2021; Shaheen et al., 2022). For instance, people have the option to drive less by choosing to walk, cycle, take public transportation, purchase electric cars or cars that use less fuel, switch off lights, use energy-efficiency lightbulbs, reuse, reduce organic waste, and buy more efficient vehicles (Peng et al., 2023). Low-carbon social innovation that involves changing behaviours on a collective level to collaborate and profit from particular accomplishments like carpooling, recycling products, etc., is one of the green innovation initiatives (Gao et al., 2022). Individuals using environmentally friendly goods, services, and renewable energy resources can also support green innovation adoption (Wirda et al., 2019).

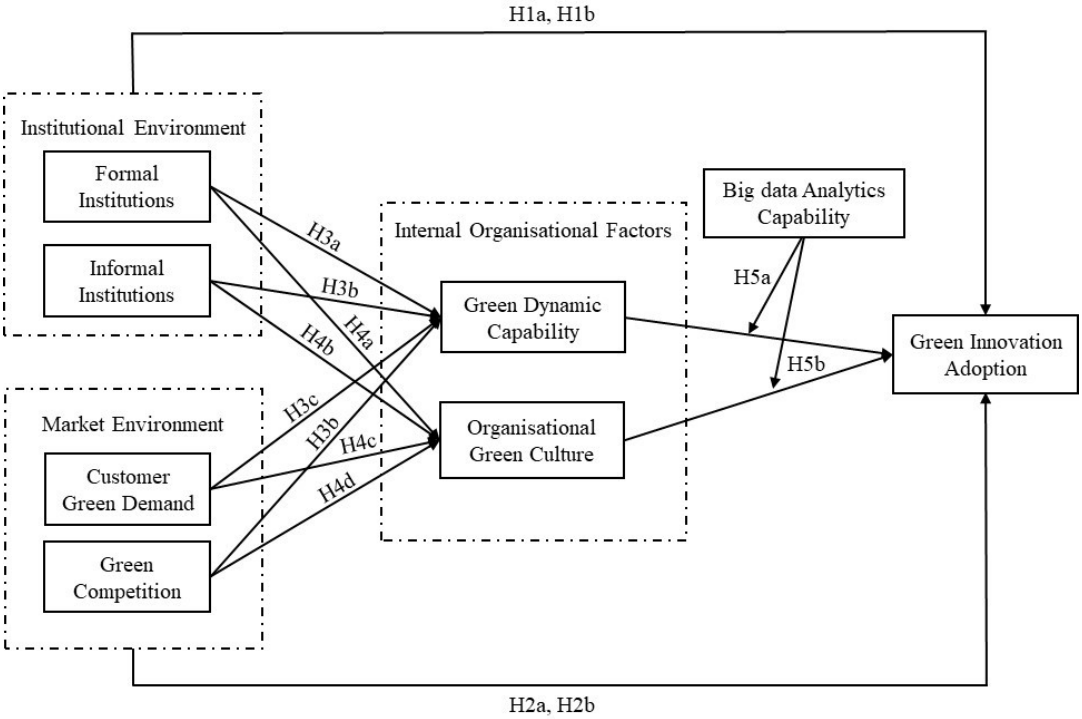
Yu et al. (2022) study measure the extent of green innovation adoption through a firm's ability to integrate digital technologies, such as big data analytics, to enhance environmental performance and track sustainability progress (Al-Khatib, 2022). Big data analytics enables enterprises to evaluate sizable data quantities and derive valuable insights (Z. Chen & Liang, 2023; Yu et al., 2022). According to Meirun et al. (2020), these insights can be used to pinpoint environmental performance improvement opportunities. The importance of environmental policy cannot be understated when it comes to motivating and directing businesses to adopt green innovation. The ecological approach offers a structure and criteria for firms to incorporate green innovation (C. Huang & Chen, 2022). Big data analytics enables them to make data-driven

decisions and modifications as needed (Z. Chen & Liang, 2023; Yu et al., 2022). Furthermore, research has shown that green innovation is often associated with long-term strategic sustainability planning, where firms prioritise eco-friendly investments, establish green partnerships, and engage in cross-industry collaborations for environmental innovation (Z. Chen & Liang, 2023). However, the current study aims to examine the role of external pressures and internal organisational factors in stimulating the adoption of green innovation in Malaysian manufacturing SMEs.

## 2.4 Proposed Conceptual Framework

The study's conceptual framework was developed based on the institutional theory, organisational cultural theory, and dynamic capability theory. The framework includes independent variables (IV), mediating, moderating, and dependent variable (DV). Figure 2.1 proposed a framework for examining how the institutional and market environment (IV) influences green innovation adoption (DV) in manufacturing SMEs in Malaysia, mediated by internal organisational factors and moderated by big data analytics capability.

**Figure 2.1: Proposed Research Model**




## 2.5 Hypothesis Development

### 2.5.1 Formal Institutions and Adoption of Green Innovation

Formal institutions are related to the coercive pressure established by governments and other governing organisations that influence the business environment (Z. Chen & Liang, 2023). In the context of green innovation adoption, formal institutions are essential in fostering an environment that encourages and supports the adoption and use of environmentally friendly strategies in manufacturing SMEs (Ali et al., 2021). These institutions can encompass emission standards, renewable energy objectives, environmental legislation, green subsidies, and incentives for environmentally friendly conduct in manufacturing SMEs (X. Wang et al., 2022). SMEs are more likely to adopt and integrate ecological-friendly practices and technology when they operate in

a regulatory framework that promotes and supports green innovation through rules and policies (Yu et al., 2022). Formal institutions can help manufacturing SMEs to develop and implement green innovation initiatives by offering incentives, resources, strict rules, and instructions. Thus, this study hypothesises that:

**H1a:** Formal institutions have a positive effect on green innovation adoption in manufacturing SMEs.

### 2.5.2 The Mediating Role of Internal Organisational Factors between Formal Institutions and Adoption of Green Innovation

This study includes two internal organisational factors: green dynamic capability and organisational green culture. It mediates a connection between formal institutions and the adoption of green innovation in manufacturing SMEs.

Formal institutions could create a supportive environment for green innovation adoption by providing a set of policies, regulations, and guidelines for sustainable practices (X. Wang et al., 2022), while on the other hand, green dynamic capability enables manufacturing SMEs to effectively respond to these institutional pressures and develop the necessary capabilities to adopt and implement green innovations (S. K. Singh et al., 2022). It allows manufacturing firms to develop and implement green innovation strategies and practices that

align with formal institutions and promote green innovation adoption (Amaranti et al., 2022). For example, manufacturing firms with strong green dynamic capability are more likely to proactively engage in green manufacturing practices and develop sustainable innovations (Amaranti et al., 2022). In the context of sustainability and environmental efficiency, green dynamic capability involves the manufacturing SMEs' capacity for innovation, learning, and adaptation (H. Singh et al., 2019; Yuan & Cao, 2022). Therefore, this study hypothesises that:

**H3a:** Green dynamic capability mediates the relationship between the formal institutions and the adoption of green innovation.

The success of green products is influenced by institutional pressure, with the role of green transformational leadership, green innovation, and green brand image are the influencing factors (J. Zhou et al., 2021). The formal institutional pressure establishes the external framework and incentives for sustainable practices, which create an environment for manufacturing SMEs to adopt green innovation (Yu et al., 2022). However, the degree to which extent SMEs embrace and successfully implement green innovation is significantly influenced by their internal green culture (Afum et al., 2020). When they have a robust green culture, they tend to have employees who are environmentally conscious, innovative, and committed to sustainability goals (Pan et al., 2022). In this context, organisational green culture plays a key mediating role by translating formal institutional pressures into actionable green innovation adoption within manufacturing SMEs. A strong green culture can motivate

employees to actively seek and implement green technologies, processes, and products, aligning the organisation's practices with the institution's sustainability goals and requirements (Pan et al., 2022). Conversely, organisations with a weak or absent green culture may struggle to embrace green innovations, even in the presence of external incentives or regulations. In short, the mediating role of organisational green culture is crucial in translating external formal institutions' influence into tangible actions, making it a key determinant of an organisation's success in adopting and integrating green innovation into its operations. Therefore, this study hypothesises that:

**H4a:** Organisational green culture mediates the connection between the formal institutions and the adoption of green innovation.

### 2.5.3 Informal Institutions and Adoption of Green Innovation

Informal institutions influence behaviour of manufacturing SMEs by shaping societal and organisational norms related to sustainability and green innovation adoption (Aslam, 2022). Informal institutions drive manufacturing SMEs to prioritise sustainability, integrate environmental concerns into decision-making processes, and adopt green technologies and sustainable practices (D. Li & Shen, 2022). For instance, more people and SMEs adopt green innovation strategies in a society where environmental stewardship and sustainable living are strongly valued (X. Liu & Lin, 2020). This could be driven by peer pressure, social pressure, or a common belief in the significance of environmental sustainability in manufacturing SMEs. Furthermore, informal

institutions like partners, competitors' practices, and the public communities positively influence green innovation adoption in manufacturing SMEs (Ali et al., 2021). The adoption of green innovations can also be facilitated by informal networks and communities that encourage knowledge sharing and education in the manufacturing sector (J.-W. Huang & Li, 2017; Zhang, Liang, et al., 2020). Thus, this study hypothesises that:

**H1b:** Informal institutions have a positive effect on green innovation adoption in manufacturing SMEs.

### 2.5.4 The Mediating Role of Internal Organisational Factors between Informal Institutions and Adoption of Green Innovation

The current research includes two internal organisational factors that mediate a connection between informal institutions and the adoption of green innovation in manufacturing SMEs.

Informal institutions like social norms and stakeholder pressure have been found to influence the development of green dynamic capabilities in manufacturing SMEs (S. K. Singh et al., 2022). The green dynamic capability is the willingness of the SMEs to continuously integrate and modify their internal and external resources, procedures, and activities to respond to environmental problems and opportunities successfully (Yousaf, 2021). The green dynamic capability enables SMEs to allocate resources wisely towards green innovation initiatives, encourages organisational learning and knowledge

creation regarding sustainability and green practices, promotes flexibility and adaptability in the face of shifting market demands and environmental regulations, facilitates collaboration and partnerships with external stakeholders, and ultimately gives manufacturing SMEs a competitive advantage (H. Li, 2022; Yu et al., 2022). In order to achieve environmental innovation, such collaboration, in particular, seeks and uses technical expertise and encourages the usage of resources, technologies, and productivity measures (Jin et al., 2019; Meirun et al., 2020). Green dynamic capability supports employees in increasing their knowledge and skills while following legislation, minimising risk tolerance and uncertainty (Joshi & Dhar, 2020). Therefore, this study hypothesises that:

**H3b:** Green dynamic capabilities mediate the connection between the informal institutions and the adoption of green innovation.

Informal institutions, which include social norms and community expectations related to the environmental sustainability, create a social and contextual backdrop for manufacturing SMEs (Lu & Yu, 2020). On the other hand, organisational green culture represents SMEs' internal values and norms that prioritise sustainability and adopt green innovation (Maniu et al., 2021). These two factors are not independent but rather interconnected in shaping SMEs' approach to green innovation adoption. Organisational green culture acts as a mediator in this relationship. It translates the external pressures and expectations created by informal institutions into practical actions in order to adopt green innovation in manufacturing SMEs (Lu & Yu, 2020). When SMEs

have a strong green culture, they align their internal practices with the informal institutions' values and norms, motivating employees to actively seek and implement green technologies and processes (Maniu et al., 2021). Conversely, organisations with a weaker green culture may struggle to embrace green innovations, even when informal pressures exist. Therefore, the strength of an organisation's green culture plays a pivotal role in determining the level to which they adopt and integrate green innovation into their operations, effectively mediating the influence of informal institutions. Therefore, this study hypothesises that:

**H4b:** Organisational green culture mediates the connection between the informal institutions and the adoption of green innovation.

### 2.5.5 Customers Green Demand and Adoption of Green Innovation

Customers are a key driving force behind the adoption of green innovation in the manufacturing sector, as demand for eco-friendly products and services intensifies (Dabija et al., 2018; Liao, 2018). The growing customer green demand is driven by heightened awareness of environmental concerns and a preference for supporting sustainable practices in manufacturing SMEs (Jun et al., 2021). Customers are actively looking for and prioritising goods that are compatible with their beliefs and have less of an environmental impact as they become more aware of their purchase actions affect the environment (Chang, 2020; Dabija et al., 2018; Yu et al., 2022). Due to the change in consumer behaviours, manufacturing SMEs face a market environment where they must

meet the rising demand for green innovation (Liao, 2018). SMEs are more likely to embrace and incorporate green innovation techniques into their operations if they are more responsive to customer demand for green products (Yousaf, 2021). SMEs that prioritise green innovations to satisfy customers' green demand while differentiating from others by providing sustainable alternatives can capture a greater market. SMEs can gain a competitive edge, boost their reputation, and draw in environmentally concerned customers by matching their goods, services, and business processes with consumer preferences for sustainability (Jun et al., 2021). Thus, this study hypothesises that:

**H2a:** Customer green demand positively influences manufacturing SMEs adoption of green innovation.

### 2.5.6 The Mediating Role of Internal Organisational Factors between Customer Green Demand and Adoption of Green Innovation

This study includes internal organisational factors that mediate a relationship between customer green demand and the adoption of green innovation in manufacturing SMEs.

Green customer demand provides opportunities for manufacturing SMEs to understand customer needs and environmental requirements, which in turn drives them to engage in green innovation adoption activities, acquire new knowledge and sense new opportunities through green dynamic capability (S.

K. Singh et al., 2022). Manufacturing SMEs acquire information on customer needs and preferences, but successful green product innovation requires integrating and sharing that information effectively (Zhao et al., 2020). A strong green customer orientation enables firms to engage in green innovative activities and acquire new knowledge that is environmental friendly. Demand-pull suggests that customer preferences for environmentally friendly products drive firms to develop dynamic capability and undertake green innovation (C. H. Wang, 2020). Likewise, green dynamic capabilities are the capacities of manufacturing SMEs to adapt to environmental demands and opportunities and to incorporate environmental concerns into their core business activities (Yu et al., 2022). In order to reach sustainability goals, one must to able to identify, acquire, and produce green sources and competencies, as well as to repurpose already-existing resources and competencies (Yuan & Cao, 2022). Amaranti et al. (2022), Yousaf (2021), Yu et al. (2022), and Yuan and Cao (2022) have examined the function of green dynamic capabilities in promoting green innovation in manufacturing SMEs in the past few years. Manufacturing firms with strong green dynamic capabilities are more likely to understand consumer demands and adjust their production processes accordingly (Xing et al., 2020). Therefore, this study hypothesises that:

**H3c:** Green dynamic capabilities mediate the connection between the customer green demand and the adoption of green innovation.

SMEs are under increasing pressure to adopt green innovation as customer preferences for environmentally friendly goods and services shift (Yu

et al., 2022). Consumers today place a greater emphasis on environmentally responsible products and services. Firms that are sensitive to this altering demand landscape are compelled not just to respond but also to anticipate and cater to these preferences (Alvesson, 2002). An organisational green culture, which includes shared values, beliefs, and customs surrounding sustainability, acts as a dynamic bridge that transfers the pressures of green customer demand into the internal organisation in manufacturing SMEs (Subramanian & Suresh, 2023). Market constraints are internalised by organisational green culture, which then influences how employees behave and make decisions (Pan et al., 2022) in SMEs. This cultural alignment encourages the growth of innovative concepts and approaches while inspiring employee commitment and feelings to adopt environmentally friendly procedures. A strong green culture encourages employees to proactively respond to customer green demand and recognise the potential for green innovation adoption in order to compete in the green market (C.-H. Wang, 2019). Therefore, this study hypothesises that:

**H4c:** Organisational green culture mediates a connection between the customer green demand and adoption of green innovation.

### 2.5.7 Green Competition and Adoption of Green Innovation

Green competition enhances manufacturing SMEs' competition for market share by offering environmentally friendly products, services, and practices (S. K. Singh et al., 2022). SMEs are forced to differentiate themselves from their competitors by practicing green innovations and

integrating sustainability into their functions as a code of beliefs and behaviour as the customer demand for sustainable solutions improves (Jo & Kwon, 2022). Green competition forces manufacturing SMEs to develop innovative green products, adopt eco-friendly manufacturing techniques, establish sustainable supply chain practices, and support initiatives that benefit the environment (Yousaf, 2021; Yuan & Cao, 2022). Green innovation approaches are more likely to be adopted and incorporated by SMEs operating in an environment of competition that values sustainability and environmental issues. Manufacturing SMEs are encouraged to invest in research and development, implement sustainability practices, and offer eco-friendly products through the existence of green competition in order to target environmentally concerned customers and gain a competitive advantage (Afum et al., 2020; Ali et al., 2021; H. Singh et al., 2019; Subramanian & Suresh, 2023). Therefore, this study hypothesises that:

**H2b:** Green competition positively effects manufacturing SMEs' adoption of green innovation.

### 2.5.8 The Mediating Role of Internal Organisational Factors between Green Competition and Adoption of Green Innovation

This study includes internal organisational factors that mediate a relationship between green competition and the adoption of green innovation in manufacturing SMEs.

Manufacturing SMEs, when operating in an environment where green competition is present, results in their increased capacity to respond to environmental challenges and opportunities effectively and flexibly through green dynamic capability (Yu et al., 2022). Essentially, manufacturing SMEs with strong green dynamic capabilities are more likely to sense risk and opportunities and proactively engage in green innovation activities in response to the competitive pressures on environmental sustainability (S. K. Singh et al., 2022). This underscores the pivotal role played by the SMEs' ability to adapt and evolve in navigating the dynamic landscape of sustainability and innovation within the manufacturing sector. SMEs can enhance their firm performance and create cutting-edge green goods, procedures, and practices by proactively responding to environmental issues and possibilities in the competitive green market (S. K. Singh et al., 2022). Green dynamic capabilities enable firms to use their resources and knowledge to build and enhance their green organisational capabilities, giving them a new competitive edge in the dynamic market (Wirda et al., 2019). Green dynamic capabilities enhance manufacturing SMEs' green innovation attempts by raising green management practices, strategic objectives, and research and development (S. K. Singh et al., 2022). Therefore, this study hypothesises that:

**H3d:** Green dynamic capability mediates the association between the green competition and the adoption of green innovation.

The green market witnesses an increase in competitiveness in manufacturing SMEs (Subramanian & Suresh, 2023). It also promotes a deeply

ingrained dedication to sustainability (X. Liu & Lin, 2020; C.-H. Wang, 2019). It fosters a collaborative and motivating environment and renders green innovation into practice in manufacturing SMEs due to the competitive pressure (Yu et al., 2022). For example, to examine the impact of green culture on environmental and economic performance, Delmas and Toffel (2004) studied a sample of U.S. manufacturing enterprises over the time. The findings demonstrated that companies with a strong green culture outperformed their competitors regarding environmental performance and enjoyed favourable financial effects, including cost reductions and revenue growth. SMEs' ability to accept and integrate green innovation is strengthened by their green culture, positioning them to succeed in a competitive environment (Afum et al., 2020). Similarly, J.-W. Huang and Li's (2017) study on green innovation and performance indicated that organisational green culture had a favourable impact on competitive advantage. Strong green cultures encouraged the adoption of green practices, which improved businesses' capacity to distinguish their goods and services and gave them a competitive edge. Therefore, this study hypothesises that:

**H4d:** Organisational green culture mediates the connection between the green competition and the adoption of green innovation.

### 2.5.9 The Moderating Role of Big Data Analytics Capability

Big data analytics capabilities are organisational dynamic capabilities that investigate, analyse, develop, and utilise big data resources for

organisational development and value addition (Tian et al., 2022). Big data analytics capabilities like data-driven decision systems increase SMEs' resources by reinforcing organisational processes and streamlining organisational and operational tasks for more efficiency (Vassakis et al., 2018). SMEs with green dynamic capabilities refer to adapting and addressing environmental challenges by adopting green innovation. Yu et al. (2022) examine those big data analytics capabilities moderates a connection concerning green dynamic capabilities and the adoption of green innovation. They find big data analytics capabilities can enhance the association between green dynamic capabilities and the adoption of green innovation. This suggests that big data analytics capability plays a vital role in adopting green innovation among manufacturing SMEs. Therefore, this study hypothesises that:

**H5a:** Big data analytics capability strengthens the connection between green dynamic capabilities and the adoption of green innovation.

Organisations with big data analytics capability in analysing enormous amounts of data can effectively use their green culture, which entails shared values, beliefs, and practices related to environmental sustainability to foster green innovation (Mahmood et al., 2023). By utilising big data analytics, SMEs can gain valuable insights and knowledge about their environmental performance, institutional environments, consumer behaviour, market trends, and technology developments, among other factors (Vassakis et al., 2018; Yu et al., 2022). With the help of this information, they may develop data-driven decisions, innovative green practices and solutions, and a green culture that

supports and leverages their unique strengths (Al-Khatib, 2022). As a result, SMEs can achieve higher environmental performance and sustainability standards by employing big data analytics capabilities to unlock the full potential of their green organisational culture. Therefore, this study hypothesises that:

**H5b:** Big data analytics capability strengthens the connection between organisational green culture and the adoption of green innovation.

## 2.6 Research Gap

Although prior studies have explored the significance of green innovation practices (Bakarim et al., 2024; Z. Chen & Liang, 2023; S. Wang et al., 2022; Waqas et al., 2021; Zhang, Liang, et al., 2020), green dynamic capability (H. Li, 2022; Sun et al., 2024; Yu et al., 2022; Yuan & Cao, 2022), stakeholder pressure (Z. Huang & Xiao, 2023; Jayaraman et al., 2023; Thomas et al., 2021; H. Wang et al., 2021), and big data analytics capability (Al-Khatib, 2022; Alkhatib, 2024; Z. Chen & Liang, 2023; Waqas et al., 2021; Yu et al., 2022) within the manufacturing sector (see Appendix: Literature Gap), there is limited empirical research that specifically focuses on green innovation adoption among manufacturing SMEs in Malaysia (Yu et al., 2022). Most of the existing literature tends to emphasise large-scale manufacturing firms or general industry settings (Z. Huang & Xiao, 2023; Sun et al., 2024; Yuan & Cao, 2022), often neglecting the distinctive challenges and contextual factors that shape manufacturing SMEs' ability to adopt green innovations.

Furthermore, studies have largely examined internal (Fang et al., 2022; Imran et al., 2021; Yousaf, 2021) and external (H. Wang et al., 2021; Zhang, Liang, et al., 2020) determinants in isolation, rather than integrating them into a unified framework that encompasses both internal organisational factors and external pressures, where limited studies have been conducted (Z. Chen & Liang, 2023; S. K. Singh et al., 2022), specifically among manufacturing SMEs in Malaysia. There is insufficient understanding of how institutional and market environments as components of the external environment interact with internal organisational factors, such as green dynamic capabilities and organisational green culture, to influence green innovation adoption among manufacturing SMEs in Malaysia. Additionally, although big data analytics capability has been recognised as a strategic resource (Shahzad et al., 2023), its potential moderating effect in strengthening the relationship between internal organisational capabilities and green innovation adoption remains limited (Yu et al., 2022), particularly in the Malaysian manufacturing SME context.

This study addresses these gaps by adopting an integrated approach that examines how Malaysian manufacturing SMEs respond to external environmental pressures (i.e., formal and informal institutions, customer green demand, and green competition), and how internal capabilities and culture mediate these responses. Moreover, it investigates moderating effect of big data analytics capabilities in enhancing the effectiveness of green innovation adoption among manufacturing SMEs in Malaysia.

## 2.7 Chapter Summary

This chapter offered a comprehensive review of the literature on green innovation and its relationship with the institutional environment, market environment, green dynamic capability, organisational green culture, and big data analytics capabilities to ensure a comprehensive understanding of the study's nature with respect to the theories (institutional theory, organisational cultural theory, and dynamic capability theory). Moreover, this chapter also elaborated on the mediating effect of green dynamic capability and organisational green culture on the connection between the external environment (institutional and market environment) and green innovation adoption, respectively. Moreover, the moderating impact of big data analytics capabilities on the relationship between green dynamic capabilities and organisational green culture towards the green innovation adoption was also addressed. Subsequently, this literature review was applied to assist the author in developing the hypotheses related to the research objectives.

The methodology used for this study is highlighted in the next chapter. It describes the data collection strategy for the research and the issues that arise during the process.

# CHAPTER THREE

# METHODOLOGY

In this chapter, the study's methodology will be covered. It discusses the overall research strategy, sample collection, and approaches to gathering information. Along with the suggested data analysis tool's evaluation and description, the pilot test and pre-test will also be carried out.

## 3.1 Research Design

A researcher's philosophy of research is how they perceive the reality. As a result, it selects a research approach. The positivist philosophy, which holds that reality is permanent, quantifiable, and knowable through the correct design of measuring tools, is appropriate for the research model because it was created from existing literature (Sekaran & Bougie, 2016). In contrast, naturalists prefer to apply a qualitative technique to investigate the uncertain reality. This study uses a quantitative research strategy to examine the model, aligning with the objectives of the study, which were to look into the relationships between different variables. The hypothetico-deductive technique used in this study adheres to the positivist approach research paradigm (Sekaran & Bougie, 2016). This approach focuses on problem identification, hypothesis development, data collection, analysis, and conclusion formulation. In contrast to inductive approaches, which are often qualitative-based, hypothetico-deductive approaches are quantitative-based. The results might be neutralised

by using tools for quantitative measurement to eliminate bias resulting from the subjective judgment of researchers.

In addition to a review of the literature, the capabilities and resources available for green innovation in manufacturing SMEs will be evaluated and explored with the help of expert advice in the pre-test. The advice of experts will be taken into consideration as this study creates a questionnaire connected to the primary goals of the study, which will provide in-depth details about the important variables linked to green innovation. Pre-testing will also be conducted to see if the survey questionnaire has any errors and whether all the questions are comprehended by the respondents (Kiong, 2021; Sekaran & Bougie, 2016). The business managers and owners will complete the questionnaire pre-tests who are actively managing manufacturing SMEs because they can provide different resources along with their different knowledge levels regarding environmental concerns and supporting green innovation (Z. Chen & Liang, 2023). Moreover, those findings will be utilised to improve the questionnaire (Sekaran & Bougie, 2016).

As chapters 1 and 2 mentioned, manufacturers were chosen as the sample for this study because the manufacturing industry mostly contributes to environmental risks (Pacini & Attafuah-Wadee, 2022). Greenhouse gas emissions in the manufacturing sector are 37.1 million tons (Our World in Data, 2019). Moreover, Malaysia has not been persistent in the environmental performance index. Hence, it has not done well and is ranked lower in 91st place (Global Innovation Index, 2022). Malaysia reports 0.7% of the global

greenhouse gas emissions, but the manufacturing sector is the third largest contributor of these emissions that is 9% in Malaysia (MGTC, 2022a). According to SME Corp. Malaysia (2022), the manufacturing sector is the second-highest contributor to the economy. Most studies on green innovation have used the manufacturing sector as their target respondent (Baggia et al., 2019; Castro & Guzmán, 2019; Z. Chen & Liang, 2023; Yu et al., 2022). Therefore, the questionnaire will be distributed to SMEs in the manufacturing sector as they can contribute to lower greenhouse gas emissions by the adoption of green innovative solutions.

### 3.1.1 Quantitative Research

It is a type of numeric technique which uses statistics and numbers for analysis (Creswell & Creswell, 2018), allowing the discovery of suitable and appropriate representations of mathematical phenomena (Sekaran & Bougie, 2016). It is possible to obtain quantified data as the samples of quantitative methods to determine the association between external factors, internal organisational factors, and the adoption of green innovations through the use of statistical analysis measurement within a population (Yu et al., 2022).

### 3.1.2 Descriptive Research

It describes the characteristics of the variables being investigated, and it cannot serve as the basis for a causal relationship (Brannen, 1992). Descriptive research is used in this study to precisely characterise the target groups that are

being examined by looking at them in their natural environment. Descriptive research may examine various factors (Siedlecki, 2020). The questionnaire is divided into two sections. Section A is a demographic section, and section B is the measurement items of each study variable.

A descriptive research design was selected for the study in order to offer a broader extent to which the interrelation between the institutional and market environment in Malaysian manufacturing SMEs' access to green innovation adoption can be mediated by internal organisational factors like green dynamic capability and green organisational culture. The moderating variable was used as big data analytics capabilities to examine the relationship between internal organisational factors and green innovation adoption. This research design offers greater flexibility, allowing researchers to effectively examine the perspectives of SME managers and owners regarding the issue, definition, or occurrence of adoption.

## 3.2 Sampling Design

### 3.2.1 Sampling Frame

With reference to Sekaran and Bougie (2016), a physical representation of every component of the population from which the sample is taken is called a sampling frame. However, in the context of this study, a comprehensive and accessible sampling frame of manufacturing SMEs in Malaysia was not available. While several directories exist, such as the SME Corporation Malaysia Directory, SME Malaysian Business Directory, National

Entrepreneurs Directory, and the Federation of Malaysian Manufacturers (FMM) Directory. These sources were found to be incomplete, inconsistent, or lacking detailed and specific information, such as updated contact details or classification by manufacturing subsectors. As a result, the study did not use any of these directories as a formal sampling frame. Instead, these directories were used purely as reference sources to identify the general characteristics and geographical distribution of manufacturing SMEs in Malaysia.

### 3.2.2 Target Population

Malaysia has a diverse and dynamic manufacturing sector, making it an ideal population to study the green innovation adoption of manufacturing SMEs. Malaysian manufacturing SMEs across various industries (including paper and allied products, chemicals and allied products, primary metal industries, machinery and computer equipment, transportation equipment, food and beverages industries, and miscellaneous manufacturing industries) were the target group for this study. Since their GDP is growing significantly and they are producing more pollution than other sectors (SME Corp. Malaysia, 2022). The manufacturing SMEs based on the SME Corp. Malaysia (2022) report, the total MSMEs are 1,173,601, with 78.7% micro-enterprises, 19.7% (231,546 firms) small enterprises, and 1.6% (18,388 firms) medium enterprises, respectively. Total manufacturing MSMEs are 65,657 (5.6%). As for this study, Micro SMEs were excluded, and the sample selection was based on manufacturing SMEs with (1) employees ranging between 5 to 200 or (2) sales turnover between RM300,000 to RM50 million (SME Corp. Malaysia, 2022).

Micro-enterprises were excluded from this study for several important reasons. First, micro-enterprises typically have limited resources, both in terms of finances and human capital, which may restrict their ability to invest in or implement green innovation practices (Maniu et al., 2021). Their small size and informal business processes often result in less structured operations compared to SMEs (Maniu et al., 2021), which may make them less likely to adopt formal green innovation strategies. Additionally, micro-enterprises generally face unique challenges such as lower levels of managerial expertise and limited access to information or support mechanisms that could facilitate green innovation adoption (Pronti et al., 2024).

### 3.2.3 Unit of Analysis

The unit of analysis is the specific entity or level of observation in research or data analysis (Sekaran & Bougie, 2016). It varies by research context and can be an individual, household, organisation, community, geographic area, event, or document, depending on the study's objectives (Sekaran & Bougie, 2016). For this study, the unit of analysis is manufacturing SMEs in Malaysia. The data is collected through questionnaires administered to owners and managers of these manufacturing SMEs, as they are more inclined to accept these newest innovations since they are proficient in technology (Kahveci et al., 2024). Moreover, they are responsible for decision-making due to their involvement in regular business operations (Mat et al., 2025). To maintain data integrity, only one response was obtained from each manufacturing SME.

### 3.2.4 Sampling Location

As mentioned above, the total number of established manufacturing SMEs in Malaysia are 47,565 (SME Corp. Malaysia, 2021). This study chose the top five states/federal territory of Malaysia based on their highest number of established manufacturing SMEs as our target locations, including Selangor, Johor, Kuala Lumpur, Perak, and Penang (SME Corp. Malaysia, 2021). The breakdown of these states/territories can be found in Table 3.1, which illustrates why these five locations were chosen based on their significant share of the total manufacturing SME population in Malaysia.

### 3.2.5 Sample Size

The sample size is the total number of people participating in the current study or the total number of overall observations (Memon et al., 2020). There are 47,565 total established manufacturing SMEs as of 2021 (SME Corp. Malaysia, 2021). In this study, the sample size was calculated using the Yamane formula where "n" is denoted by sample size, "N" is the population size, and "e" is the level of precision.

$$n = \frac{N}{1 + N(e)^2} = \frac{47{,}565}{1 + 47{,}565\ (0.07)^2} = 203.21 \sim 204$$

On the basis of Yamane's (1967) formula, a sample size of 204 was advised. Since the behaviour of the sample is homogeneous, a precision rate of

+7% was recommended. The Yamane formula was able to calculate the appropriate sample size. In previous research, this formula was used to determine the ideal sample size when specific presumptions were achieved (Jun et al., 2021; Noranarttakun & Pharino, 2021b). Furthermore, a survey is determined to be appropriate if it has a precision level below 10% and a confidence interval level exceeding 90% (Taherdoost, 2016). Moreover, as per the rules of thumb by Roscoe (1975), a sample size between 30 to 500 is acceptable (Sekaran & Bougie, 2016).

### 3.2.6 Sampling Technique

In this research, the target respondents were managers and owners of the manufacturing SMEs in Malaysia. The study used a type of non-probability approach known as quota sampling, due to the absence of a complete and accessible sampling frame with detailed and up-to-date contact information of SME managers or owners. Although several directories such as the SME Corporation Malaysia Directory, SME Malaysian Business Directory, National Entrepreneurs Directory, and the Federation of Malaysian Manufacturers Directory were referred to for identifying the target population, these sources lacked sufficient granularity such as verified individual-level contact details required for the implementation of probability sampling techniques. Therefore, quota sampling was deemed most appropriate, considering the feasibility, accessibility of the population, and time and cost constraints of this study. It is low-cost, time-saving, and adequately represents the minority elements technique (Sekaran & Bougie, 2016). Quota sampling refers to the gathering of

data from a population that is segmented into subgroups (Sekaran & Bougie, 2016). If the researcher looks at the entire population, difficulties may include feasibility, time, and cost limitations. Hence, in order to accomplish this study's goal, this technique allows a researcher to divide a fixed quota for each subgroup based on specific criteria to minimise sampling error and restrict generalisation (Rahi, 2017).

The quota sampling technique comprised a number of steps, as the target population is manufacturing SMEs in Malaysia. Table 3.1 shows the summary of the total number of established manufacturing SMEs as per the states/territory. According to the SME Corp. Malaysia (2021), Selangor (9,530 firms), Johor (7,787 firms), Kuala Lumpur (5,185 firms), Perak (4,298 firms), and Penang (4,021 firms) have the highest number of established manufacturing SMEs, which is almost 65% (30,821 firms) of the overall population shown in Table 3.1. Therefore, due to time constraints, the higher quota was assigned to Malaysia's top five states/territory having a higher ratio of established manufacturing SMEs. Hence, a sample of 204 respondents was proportionally distributed using the below formula across these five regions. The calculations for sample size per state are shown in the Appendix (Adjusted Sample Size Calculation for Top 5 States).

$$Sample\ size\ for\ a\ state = \left(\frac{Population\ share\ (\%)}{64.8\%}\right) * 204$$

After allocating the quota to each location, a judgmental (purposive) approach was applied in order to collect the data from the manufacturing SMEs

presented in those locations. The term "judgmental" refers to purposive sampling, which was employed after the quota allocation for each location. While the study referenced several directories, these were found to be unavailable, incomplete, and lacked detailed, up-to-date information. As a result, a comprehensive sampling frame could not be constructed, making it unfeasible to use probability sampling techniques. Given these limitations, judgmental sampling was chosen as a practical solution. This method allowed the researcher to ensure and collect data from only the top management (managers and owners) of manufacturing SMEs within the predefined quotas. Despite the availability of some directories, the lack of details and the geographical spread of the SMEs made judgmental sampling the most feasible and efficient approach for data collection within the study's constraints.

**Table 3.1: Summary of Manufacturing SMEs Sample Size by States/Territory**

| States/Federal Territory | No. of established Manufacturing SMEs* | Population by States/Territory (%) | Sample size |
|---|---|---|---|
| Selangor | 9,530 | 20.0% | 63 |
| Johor | 7,787 | 16.4% | 52 |
| Kuala Lumpur | 5,185 | 10.9% | 34 |
| Perak | 4,298 | 9.0% | 28 |
| Penang | 4,021 | 8.5% | 27 |
| Kedah | 3,214 | 6.8% | |
| Sarawak | 2,512 | 5.3% | |
| Terengganu | 2,010 | 4.2% | |
| Kelantan | 1,830 | 3.8% | |
| Negeri Sembilan | 1,826 | 3.8% | |
| Pahang | 1,752 | 3.7% | |
| Sabah | 1,751 | 3.7% | |
| Melaka | 1,479 | 3.1% | |
| Perlis | 370 | 0.8% | |
| **Total** | **47,565** | **100%** | **204** |

*Source: SME Corp. Malaysia (2021)

The sample size for each location was first scaled at the total sample size of 204 based on the top 5 locations that have the highest percentage share of almost 65% of established Malaysian manufacturing SMEs, then the quota was assigned to them. The data of established manufacturing SMEs presented in those locations was extracted from the SME Corp. Malaysia (2021) report. Judgmental sampling was applied later in order to ensure the data was collected from top management working in those locations. As Selangor has the most established manufacturing SMEs, most responses (63) were collected from there. Similarly, responses were gathered from Johor (52), Kuala Lumpur (34), Perak (28), and Penang (27) based on purposive sampling.

## 3.3 Data Collection Methods

### 3.3.1 Primary Data

It is the information that is obtained through experience and from the original source (Paradis et al., 2016). Since this has not been altered by anyone, it is more trustworthy and real (Kabir, 2016). The primary study tool was a survey-based questionnaire conducted physically. This method enables quick interaction with respondents and facilitates immediate feedback collection. Physical surveys often yield higher response rates and allow real-time clarification of queries, reducing potential misunderstandings and human error.

This study focuses on green innovation adoption among manufacturing SMEs currently present in Malaysia. Given the absence of an accessible and

complete sampling frame, the researcher employed quota sampling to collect data from a diverse and representative cross-section of manufacturing SMEs.

To support the identification of the target population and quota categories, multiple directories namely the SME Corporation Malaysia Directory, SME Malaysian Business Directory, National Entrepreneurs Directory, and the Federation of Malaysian Manufacturers Directory, were used solely as reference tools to understand the broader SME landscape. These directories enabled the establishment of relevant sampling quotas based on company characteristics, including location, sector, and size. The overlap of firms across directories is possible, and it was addressed through cross-checking and data cleaning to avoid duplication.

### 3.3.2 Ethical Clearance and Approval

Prior to the commencement of data collection, the researcher submitted an ethical clearance application to the university. This step ensured that the research adhered to the necessary ethical standards for conducting research involving human participants. After receiving the university's approval for the study, the researcher proceeded with the data collection process, in full compliance with the approved ethical guidelines.

### 3.3.3 Data Collection Procedures

Once ethical clearance was obtained, the researcher initiated the data collection phase, which spanned a total duration of seven months focusing on digital distribution and physically visiting manufacturing SMEs in selected states and territory across Malaysia. Initially, efforts to distribute the questionnaire digitally via email, LinkedIn, QR codes, and Google Forms resulted in minimal responses. To address this, the researcher sought university approval to conduct physical surveys in the form of ethical clearance. The survey was administered in person, with the researcher approaching managers and owners of manufacturing SMEs, explaining the study's objectives, and distributing the questionnaires. This direct interaction allowed for real-time clarification of questions, ensuring higher-quality responses.

To further increase participation and ensure a diverse sample, the researcher attended career fairs and industrial exhibitions in the target states and federal territory. These events facilitated face-to-face interactions with professionals from the manufacturing SMEs, improving response rates and providing opportunities to clarify the survey's purpose and questions. Quota sampling was employed to ensure a diverse and representative sample, guided by criteria such as location (states/federal territory) of the manufacturing SMEs. The use of directories such as the SME Corporation Malaysia Directory, SME Malaysian Business Directory, National Entrepreneurs Directory, and the Federation of Malaysian Manufacturers Directory helped in identifying relevant manufacturing SMEs that met the required criteria.

Follow-up visits and communications were made to address any non-responses and ensure timely data collection. Through this multi-faceted approach, the study effectively maximised response rates and collected accurate and meaningful data.

### 3.3.4 Pre-Test

To ensure that all the measures of the pre-test worked properly in a range of study contexts (Kumar et al., 2017). Two academics with expertise in green practices and one corporate specialist from manufacturing SMEs reviewed the questionnaire. The pre-test questionnaire was shared with them due to their expertise in the related field in order to assess the instrument's relevance and understanding necessary to ensure content validity (Kiong, 2021). In response to their suggestions, the questionnaire was modified to make the questions easier to comprehend and increase the quality of the questionnaire. Table 3.2 shows the summary of the feedback provided by industrial and academic experts.

**Table 3.2: Summary of the Pre-testing Feedback**

| Section | Recommendations/Suggestions | Corrections made |
|---|---|---|
| Section A: Firm & Personal Information | Request additions to the following description:<br>Q5: "CEO/Director" to "CEO/**CFO**/Director"<br>Q6: Add "**Electrical and Electronic Equipment**"<br>Q6: "Miscellaneous Manufacturing Industries" to "Miscellaneous Manufacturing Industries **(Medical** | Suggestions have been revised. |

| | | |
|---|---|---|
| | **Equipment and Supplies, Jewellery, Sporting Goods, Toys, and Office Supplies, etc)**" | |
| Section B: Part 1a (Formal Institutions) | Propose modifications to the following attribute:<br>A2: "must not be exceeded or must be obeyed" to "**must be obeyed**"<br>A4: "various areas" to "**various manufacturing processes**" | Suggestions have been revised. |
| Section B: Part 1b (Informal Institutions) | Propose modifications to the following attribute:<br>A1: "Partners...activities." to "**Business** partners...activities **in order to reduce environmental effects**"<br>A3: "Society puts" to "**Societal norms and culture** put"<br>A4: "organisations, communities, and media" to "organisations **and social** media" | Suggestions have been revised. |
| Section B: Part 2a (Customers Green Demand) | Propose modifications to the following attribute:<br>A3: "Customer green demands motivate us to...sustainability." to "**My organisation gets** motivated to...sustainability **due to the Customer's green demands**." | Suggestions have been revised. |
| Section B: Part 2b (Green Competition) | Propose modifications to the following attribute:<br>A4: "environmental concepts" to "environmental **friendly strategies**" | Suggestions have been revised. |
| Section B: Part 3 (Green Dynamic Capability) | Propose modifications to the following attribute:<br>A1: "efficiency and effectiveness" to "efficiency"<br>A2: "quickly monitor" to "monitor" and "new green" to "**environmental friendly**"<br>A3: "generate, integrate, share, convert" to "integrate, share"<br>A4: "develope" to "**develop**"<br>A5: "integrating and managing" to "integrating" | Suggestions have been revised. |
| Section B: Part 5 (Big Data Analytics Capability) | Propose modifications to the following attribute:<br>A1: "tools and technologies" to "technologies"<br>A2: "prediction or analysis" to "analysis **on advanced tools**" | Suggestions have been revised. |

| | | |
|---|---|---|
| | A5: "applications or information" to "information" | |
| Section B: Part 6 (Green Innovation) | Propose modifications to the following attribute:<br>A5: "material and waste" to "waste material" | Suggestions have been revised. |

Note:
Q = Question number
A = Attribute number

### 3.3.5 Pilot Test

After the pre-test, a pilot test was also conducted to ensure the validity and reliability of the questionnaire. Upon identifying the problem, the questionnaire was also modified prior to its final distribution. For the pilot test, Browne recommends a sample size of at least 30 responses (Whitehead et al., 2016). Therefore, 30 responses were collected from managers and owners working in manufacturing SMEs in this pilot study. The pilot study's questionnaire was distributed through online platforms like email, LinkedIn, and other social media tools. Their emails and other social media accounts were searched on the manufacturing SMEs directories and using the LinkedIn search filter. The researcher may access them through LinkedIn chat for better reach of the questionnaire responses. There was also a reliability test known as Cronbach's alpha test. According to the Cronbach alpha values, the optimal range of 0.70 and above is acceptable (Irawan et al., 2021). Consequently, the data was gathered, and the findings were produced using reliable data. However, the pilot study responses that were obtained from the manufacturing SMEs were not included in the final study sample analysis. Table 3.3 represents the summary of construct validity from the pilot test.

**Table 3.3: Pilot Test Summary**

| Validity | Assessment | Threshold | Value | Result |
|---|---|---|---|---|
| Construct Validity | Cronbach's Alpha | Values > 0.70 | 0.897 to 0.966 | Pass |
| Construct Validity | Convergent Validity - AVE | Values > 0.50 | 0.749 to 0.880 | Pass |
| | Discriminant Validity | | | Pass |
| a) | Heterotrait-Monotrait (HTMT) | Values < 0.90 | a) 0.094 to 0.881 | |
| b) | Cross loading | Values > 0.70 | b) 0.756 to 0.955 | |

## 3.4 Questionnaire Design

The questionnaire was filled out in English. The questionnaire was divided into two sections.

Section A includes a demographic section based on nominal and ordinal scales. The nominal scale describes how the subject is divided into various groups. There is neither sequence nor measure of distance among the variables (Sekaran & Bougie, 2016). Category or dichotomous scale are other names for the nominal scale. However, an ordinal scale involves organising people, things, or attitudes along a continuum based on the characteristic being measured. Given that the variables are ordered to reflect variances, it allows researchers to rank the subject in terms of priority (Sekaran & Bougie, 2016). Section A includes state, gender, age, education level, job position, number of years' experience, industry in the manufacturing sector, firm age, number of full-time employees, and sales turnover.

Whereas section B includes measurement items of the study variables like institutional environment, market environment, internal organisational factors (green dynamic capabilities and green organisational culture), big data analytics capability, and SME's access to the adoption of green innovation. All items were measured in section B using the interval scale of 7-point Likert-type scales, where 1 denotes strongly disagree and 7 represents strongly agree, in order to maximise reliability and reflect true judgment (Symonds, 1924). Seven-point Likert scales were more accurate and indicated stronger correlations with t-test results. Additionally, seven-point scales are more widely used and supported than five-point scales (Preston & Colman, 2000). Table 3.4 provides a summary of the questionnaire design used in the study.

**Table 3.4: Questionnaire Design Summary**

| Section | Quantity of items | Focus of items | Type of scale |
|---|---|---|---|
| A | 10 | Firms' information and the respondents' demographic | Ordinal and Nominal |
| B | 16 | Independent variables | Interval |
| B | 10 | Mediating variables | Interval |
| B | 5 | Moderating variable | Interval |
| B | 5 | Dependent variable | Interval |

### 3.4.1 Measurement Items for Questionnaire

As stated above, the questionnaire's measurement items for section B were evaluated based on an interval of 7-point Likert-type scales.

Formal institutions refer to written state-provided restraints like laws, rules, and contracts (Z. Chen & Liang, 2023). The current study adapted the questions from M. Zhou et al. (2021), in which formal institutions were

examined through pollution control, environmental regulations, and standards. These components can encourage manufacturing SMEs to explore more options in order to adopt green innovation.

Informal institutions are the norms, ethics, and cultures that are part of the social system and upheld by the public and communities (Ji et al., 2019). This research measured environmental organisations, communities, and media pressure using the study of S. K. Singh et al. (2022) and M. Zhou et al. (2021).

For customer green demand, the research of Cai and Li (2018) and Z. Chen and Liang (2023) were adapted as measurement items. The loyalty of consumers depends upon environmental friendly products and the company's dedication for the sustainability of the environment and business (S. K. Singh et al., 2022).

Competition for ecological sustainability has gained in recent years, resulting in a better green image, enhanced market share, and increased competitive advantage (Yu et al., 2022). In this study, the green competition measures were adopted from Cai and Li (2018) and Z. Chen and Liang (2023) research.

Green dynamic capability helps organisations to absorb, learn, generate, integrate, convert, and apply new green knowledge (Yuan & Cao, 2022). Green dynamic capability helps firms to allocate their resources by adopting green innovation (Yu et al., 2022). This study adopted the measurement items from

Yousaf (2021) and Yuan and Cao (2022) research to examine the willingness of Malaysian manufacturing SMEs to embrace green innovation.

Organisational green culture ensures the firm's consciousness related to ecological protection (Ali et al., 2021). The study of C.-H. Wang (2019) and Yeşiltaş et al. (2022) was adapted as measurement items. The organisational policy, efforts, priorities, and values measure organisational green culture's role in adopting green innovation.

Big data analytics capability helps organisations apply data visualisation strategies, analyse, and offer dashboard information that decreases environmental risks and enhances green innovation adoption (Z. Chen & Liang, 2023). In this research, big data analytics capabilities were examined using the study of Dubey et al. (2018).

Generally, manufacturing SMEs' access to green innovation adoption is an important factor in better performance and continuing growth of the firms and environmental sustainability (Yu et al., 2022). This research measures manufacturing SMEs' access to green innovation adoption as in the study of Ali et al. (2021) and M. Zhou et al. (2021).

**Table 3.5: Summary of Adaptation of the Measurement Items**

| Constructs | Section | Number of items | Sources of adoption |
|---|---|---|---|
| Formal Institutions | Section B | 4 | (M. Zhou et al., 2021) |
| Informal Institutions | Section B | 4 | (M. Zhou et al., 2021) |

| | | | |
|---|---|---|---|
| Customers Green Demand | Section B | 4 | (Cai & Li, 2018)<br>(Z. Chen & Liang, 2023) |
| Green Competition | Section B | 4 | (Cai & Li, 2018)<br>(Z. Chen & Liang, 2023) |
| Green Dynamic Capabilities | Section B | 5 | (Yousaf, 2021)<br>(Yuan & Cao, 2022) |
| Organisational Green Culture | Section B | 5 | (C.-H. Wang, 2019)<br>(Yeşiltaş et al., 2022) |
| Big Data Analytics Capability | Section B | 5 | (Dubey et al., 2018) |
| Green Innovation Adoption | Section B | 5 | (Ali et al., 2021)<br>(M. Zhou et al., 2021) |

**Table 3.6: Questionnaire Items Summary**

| Constructs | Measurement items |
|---|---|
| Formal Institutions | 1. My manufacturing organisation faces various environmental regulations that urge us to adopt pollution control in production processes.<br>2. My manufacturing organisation faces a set of environmental regulations that present standards that must be obeyed.<br>3. My manufacturing organisation faces a set of environmental regulations that stipulate the need to pay pollution fines for exceeding pollution limits.<br>4. My manufacturing organisation faces environmental regulations in various manufacturing processes. |
| Informal Institutions | 1. Business partners put pressure on my organisation to adopt environmentally friendly activities in order to reduce environmental effects.<br>2. Competitors' practices put pressure on my organisation to adopt environmentally friendly strategies.<br>3. Societal norms and culture put pressure on my organisation to engage in environmentally friendly procedures.<br>4. The public, including third-party environmental organisations and social media, put pressure on my organisation to adopt environmentally beneficial activities. |
| Customers Green Demand | 1. My organisation’s loyal consumers are profoundly concerned about the environment.<br>2. My organisation’s loyal customers demand environmentally friendly products. |

| | |
|---|---|
| | 3. My organisation gets motivated to improve our dedication to sustainability due to the Customer's green demands.<br>4. My organisation's loyal consumers often address environmental concerns. |
| Green Competition | 1. My organisation develops a green image compared to competitors via environmental standards.<br>2. My organisation's main competitors establish environmental guidelines for their business activities.<br>3. My organisation can enhance market share through the implementation of environmental standards.<br>4. My organisation can gain a competitive edge by adopting environmental friendly strategies. |
| Green Dynamic Capabilities | 1. My organisation can improve work efficiency by integrating internal and external resources.<br>2. My organisation has the ability to monitor the environment in order to identify environmental friendly possibilities.<br>3. My organisation can absorb, learn, integrate, share, and apply new green knowledge.<br>4. My organisation is able to successfully allocate resources to develop green innovations.<br>5. My organisation has the capability of successfully integrating specialised green knowledge within the organisation. |
| Organisational Green Culture | 1. My organisation makes an effort to ensure that every employee understands the importance of environmental preservation.<br>2. My organisation aims to make environmental protection a priority in all departments.<br>3. My organisation has a clear policy statement encouraging sustainability in every business operation aspect.<br>4. Environmental preservation is a high-priority activity in my organisation.<br>5. My organisation places a central corporate value on environmental preservation. |
| Big Data Analytics Capability | 1. My organisation possesses advanced technologies for data analysis.<br>2. My organisation gathers data from various sources and uses it for analysis on advanced tools.<br>3. My organisation applies data visualisation strategies to aid decision-makers in comprehending complex information gathered from vast quantities of data.<br>4. My organisation's dashboards offer information that is useful for necessary diagnostics. |

| | |
|---|---|
| | 5. My organisation has connected dashboard information with the manager's communication devices. |
| Green Innovation Adoption | 1. My organisation selects ingredients for products that minimise environmental risks.<br>2. My organisation optimises energy consumption during the manufacturing process.<br>3. My organisation ensures that the product becomes recyclable and reusable.<br>4. My organisation selects a manufacturing process that generates minimal waste and produces the minimum environmental pollution.<br>5. My organisation recycles and reuse waste material generated throughout the manufacturing process. |

## 3.5 Data Analysis Tool

### 3.5.1 Descriptive Statistics and Inferential Analysis

Descriptive statistics are used to compute, evaluate, and synthesise collected data in an accessible, usable, rational, and goal-oriented means (Vetter, 2017). Descriptive statistics is used to display obtained data in the form of charts and tables. The postulated hypothesis was then used to validate it using inferential analysis to draw assumptions, conclusions, predictions, and explanations about the population's characteristics.

### 3.5.2 SmartPLS Software

It is regarded as the greatest analysing statistical data tool because of its flexibility, less bound by regulations and laws. It enables academicians to utilise undistributed data and examine causal pathways (Kiong, 2021).

### 3.5.3 Structural Equation Modelling (SEM)

Structural Equation Modelling (SEM) is a sophisticated multivariate technique increasingly used in scientific research to test and determine multivariate causal relationships. SEM is distinct from other modelling techniques in examining both the direct and indirect effects of considered causal relationships. SEM is used to assess and investigate correlations between observable and latent variables (Kiong, 2021). This statistical technique combines two techniques: confirmatory factor analysis (Fan et al., 2016) and path analysis. The confirmatory factor analysis aims to estimate latent psychological traits, whereas path analysis draws a path diagram to show the link between variables causally. It may be viewed as an adaptable framework that allows the researchers to create and examine intricate interactions between several variables in order to support the hypothesis.

### 3.5.4 Partial Least Squares Structural Equation Modelling (PLS-SEM)

This study used the partial least squares structural equation modelling (PLS-SEM) method. Instead of adhering to any theory, the goal of this study is to forecast individual behaviour. As a result, this model may be applied as the purpose of the study is to support or refuse the hypothesis that has been put out (Sekaran & Bougie, 2016). It is necessary to go through the measurement model assessment and structural model.

In the current study, PLS-SEM was chosen over CB-SEM because previous research by Dash and Paul (2021) showed that better construct validity and reliability are often produced using PLS-SEM, particularly when it comes to average variance extracted and composite reliability results. Moreover, PLS-SEM is considered more flexible compared to CB-SEM, which has higher data requirements. The utilisation of PLS-SEM software enhances the quality of this study on green innovation adoption in manufacturing SMEs as it provides trustworthy and reliable results even when the sample size is smaller.

#### 3.5.4.1 Measurement Model Assessment

To ensure that each construct is unique from the others and to demonstrate the relationship of each variable to the relevant development, the measurement model evaluation is conducted (J. F. Hair et al., 2010). Convergent and discriminant validity are the two concept validities considered in this model evaluation. It shouldn't be uncorrelated with diverse and irrelevant variables but also shouldn't be uncorrelated with just relevant ones (Krabbe, 2017). Convergent validity indicates how well the new scale is correlated with the same concept's existing variables and measures. This is attained once the threshold values of the Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) coefficients have been fulfilled. To obtain convergent validity, the AVE values must be 0.50 or greater (Henseler et al., 2015), whereas composite reliability and Cronbach's alpha should be more than 0.70.

Discriminant validity, meanwhile, refers to how much the ideas really differ from one another in experiments. Additionally, it evaluates how differently the overlapping conceptions differ from one another (Sekaran & Bougie, 2016). It can be measured using the Heterotrait-Monotrait (HTMT) ratio (Henseler et al., 2015). The Heterotrait-Monotrait (HTMT) ratio is a vital statistical tool for evaluating the discriminant validity of latent constructs. The HTMT ratio is a measure used for determining the strength of correlations between similar constructs and relationships between different constructs. The cutoff threshold for the HTMT ratio's discriminant validity is below 0.90, showing a discriminant validity between two reflective constructs (Henseler et al., 2015).

#### 3.5.4.2 Structural Model Assessment

The estimates and hypotheses test for the causal relationships between exogenic and endogenic constructs in the route diagram are used to evaluate the structural model (J. F. Hair et al., 2019). Collinearity was computerised as part of the assessment process by reporting values of the variance inflation factor (Sukendro et al., 2020). There shouldn't be a variance inflation factor (VIF) of more than 10, as this will reveal any multicollinearity problems.

The route coefficients must then be used to estimate the hypothesised connections between the components. To formulate the hypothesis, t-value, R square, PLSpredict, and F square (effect size) are used in evaluating route coefficient (Chinnaraju, 2025). The appropriate values for a two-tail test include

significance level of 1% (t = 2.57), 5% (t=1.96), and 10% (t = 1.65) (J. F. Hair et al., 2017). The R-square values of 0.75, 0.50, or 0.25 are characterised as substantial, moderate, and weak respectively (J. F. Hair et al., 2014, 2017). The value of PLSpredict for the constructs must be greater than 0 to allow for construct cross-validated prediction performance. Otherwise, the predictive 2 significance of the constructs is not guaranteed. Additionally, the effect of a predictive construct on an endogenous component is measured by F Square (effect size) (J. F. J. Hair et al., 2014). The three different degrees of indication are small effect size of 0.02, medium effect size of 0.15, and big effect size of 0.35 (Tan et al., 2018).

## 3.6 Conclusion

This chapter provides a general description of the research methodology, covering the types of research and approaches used in the data collection, accompanied by justifications for each methodological decision. It includes research designs, sample designs, collecting data techniques, and suggested data analysis tools, providing in-depth data collection process knowledge. The method of data analysis will be discussed in further detail in the following chapter.

# CHAPTER FOUR

# DATA ANALYSIS

This chapter will present the results of the data analysis attained from the SmartPLS 4 software. It will also present the overall research findings gathered through the questionnaire, which helps researchers offer valuable insights that address the study's objectives.

## 4.1 Response Rate

A total of 1,550 questionnaires were distributed to the target audience in the physical survey over a period of seven months, from March 2024 to October 2024. The overall response rate was 13.87%, which was relatively low. The minimum needed sample size of 204 was marginally exceeded by the 215 responses that were obtained. Eleven responses were excluded during the data cleaning process as they did not meet the eligibility criteria. Specifically, two responses were excluded because the participants were not located within the top five states or federal territory as per the sampling location requirement and five did not meet the SMEs criteria due to having more than 200 employees along with annual revenue greater than RM50,000,000. Moreover, one was not a decision-maker within their organisation, comparatively working below the managerial role, and three respondents provided incomplete responses. The SmartPLS 4 software was then used to assess the remaining 204 questionnaires.

## 4.2 Descriptive Analysis of the Demographic Profiles

### 4.2.1 Demographic Analysis of the Respondents

As outlined in Section A of the questionnaire, respondent demographic information was represented from Tables 4.1 to 4.4 to facilitate clearer results. Following this, descriptive analysis was conducted to offer a quantitative data overview.

The information presented in Table 4.1 below demonstrates that the surveys were filled out by males (66.2%), while the remaining questionnaires were filled out by females (33.8%).

**Table 4.1: Gender**

| Gender | Frequency | Percentage |
|---|---|---|
| Male | 135 | 66.2% |
| Female | 69 | 33.8% |

Table 4.2 shows the age distribution of the respondents. The most respondents were in the younger age groups, with 44.1% aged 20-29 years and 31.4% aged 30-39 years. These categories accounted for 75.5% of the total sample, showing that the most of respondents were under the age of 40 years. In comparison, fewer respondents were in the older age brackets: 21.1% were 40-49 years old, and 3.4% were over 50. There were no responders aged under 20. This age distribution indicated that most of the respondents were between 20 to 39 years, with a smaller number of the responders aged 40 or older.

**Table 4.2: Age Group**

| Age group | Frequency | Percentage |
|---|---|---|
| Below 20 years | 0 | 0.0% |
| 20 – 29 years | 90 | 44.1% |
| 30 – 39 years | 64 | 31.4% |
| 40 – 49 years | 43 | 21.1% |
| Above 50 years | 7 | 3.4% |

The information illustrated below in Table 4.3 reveals that most of the respondents were bachelor's degree holders with 41.2% followed by the Master and PhD degree holders with 30.9%. Finally, the respondents with the lowest ratio of 8.8% had completed high school whereas, 19.1% of the respondents were certificate and diploma holders.

**Table 4.3: Level of Education**

| Level of education | Frequency | Percentage |
|---|---|---|
| No formal education | 0 | 0.0% |
| Primary school | 0 | 0.0% |
| High school | 18 | 8.8% |
| Certificate holders & Diploma | 39 | 19.1% |
| Bachelor's degree | 84 | 41.2% |
| Master & PhD | 63 | 30.9% |

Table 4.4 outlined that Selangor and Johor states had 56.4% proportion of respondents which is 30.9% and 25.5% respectively. The third highest proportion of the respondents was located in the Federal Territory of Kuala Lumpur (16.7%). Lastly, Perak and Penang states had almost equal share of 13.7% and 13.2% respectively.

**Table 4.4: State/Federal Territory Location**

| State/Federal Territory | Frequency | Percentage |
|---|---|---|
| Selangor | 63 | 30.9% |
| Johor | 52 | 25.5% |
| Kuala Lumpur | 34 | 16.7% |
| Perak | 28 | 13.7% |
| Penang | 27 | 13.2% |

### 4.2.2 Demographic Analysis of the Firms

Section A of the questionnaire also represents firms' profiles. The respondents were asked to answer questions related to the firms' demographics which are shown in Tables 4.5 to 4.8. Each table provides brief explanations to help with the display and analysis of firm-specific information. This pattern provides a clear frequency distribution, translating raw data into an understandable manner that displays essential information about the entire sample and assists in identifying visual trends.

Table 4.5 shows that most of the respondents (66.7%) were Managers or Assistant Managers, while a smaller portion were Owners/Company Founders (19.6%) and CEOs, CFOs, or Directors (13.7%). This distribution highlights that most of the respondents occupy managerial roles, which have direct involvement in the day-to-day operations and decision-making processes within their organisations. A smaller proportion of respondents hold top-level management positions, such as Owners/Company Founders and CEO/CFO/Directors.

**Table 4.5: Job Positions**

| Job position | Frequency | Percentage |
|---|---|---|
| Owner/Company Founder | 40 | 19.6% |
| CEO/CFO/Director | 28 | 13.7% |
| Manager/Assistant Manager | 136 | 66.7% |

Table 4.6 categorises respondents by manufacturing industry. The largest segment, 19.6%, represented machinery and computer equipment manufacturing, followed by electrical and electronic equipment at 17.2%. Food and beverages industries accounted for 13.7%, and chemicals and allied products represented 12.7% of the sample. Respondents from miscellaneous manufacturing industries, which included diverse sectors like medical equipment, jewellery, sporting goods, toys, and office supplies made up 11.8%. Smaller industry segments included paper and allied products at 9.8%, transportation equipment at 6.4%, primary metal industries at 5.9%, and furniture industries at 2.9%. This distribution highlights a diverse representation across Malaysia's manufacturing sectors, with a concentration in technology and machinery-oriented industries.

**Table 4.6: Manufacturing Industry**

| Manufacturing industry | Frequency | Percentage |
|---|---|---|
| Paper and Allied Products | 20 | 9.8% |
| Chemicals and Allied Products | 26 | 12.7% |
| Primary Metal Industries | 12 | 5.9% |
| Machinery and Computer Equipment | 40 | 19.6% |
| Electrical and Electronic Equipment | 35 | 17.2% |
| Transportation Equipment | 13 | 6.4% |
| Food and Beverages Industries | 28 | 13.7% |
| Miscellaneous Manufacturing Industries (Medical Equipment and Supplies, Jewellery, Sporting Goods, Toys, and Office Supplies, etc) | 24 | 11.8% |
| Furniture Industries | 6 | 2.9% |

The details regarding the number of full-time employees in Table 4.7 highlight that 53.4% of respondents were working in an organisation with a range of 5 to 75 total employees. Subsequently, 46.6% of the respondents were in 76 to 200 employees' firms. Lastly, there were no respondents from firms with fewer than 5 employees or more than 200 employees. Hence, it is shown that all of the respondents belong to firms with 5 to 200 employees.

**Table 4.7: Number of Full-time Employees**

| No. of Employees | Frequency | Percentage |
|---|---|---|
| Less than 5 | 0 | 0.0% |
| 5 – 75 | 109 | 53.4% |
| 76 – 200 | 95 | 46.6% |
| More than 200 | 0 | 0.0% |

Table 4.8 provides an overview of the estimated annual revenue of the organisations. 54.4% reported between RM15,000,000 to less than RM50,000,000, whereas 45.6% fell within the RM300,000 to less than RM15,000,000 range. Lastly, there were no respondents from organisations with annual revenues either below RM300,000 or above RM50,000,000. This indicates that most respondents were from companies with annual revenues between more than RM300,000 and less than RM50,000,000.

**Table 4.8: Estimated Revenue per Year**

| Revenue per year | Frequency | Percentage |
|---|---|---|
| Less than RM300,000 | 0 | 0.0% |
| RM300,000 to less than RM15,000,000 | 93 | 45.6% |
| RM15,000,000 to less than RM50,000,000 | 111 | 54.4% |
| More than RM50,000,000 | 0 | 0.0% |

The data represented above in Table 4.7 and 4.8 aligns with the official definition of SMEs in Malaysia as outlined by SME Corp. Malaysia (2021).

According to the SMEs definition, a manufacturing SME is classified based on either of two criteria: an annual revenue between RM300,000 and RM50 million or a workforce size between 5 and 200 employees (SME Corp Malaysia, 2022). The above findings confirm that the sample consists of organisations that meet the criteria for SME classification, as they fall within the defined ranges of annual revenue and employees.

## 4.3 Statistical Analysis

The study employed PLS-SEM to test the research model and evaluate the hypotheses. Known for its suitability with smaller sample sizes of 204 (Hair et al., 2014), PLS-SEM was an appropriate choice for the analysis conducted in this study. The analysis highlights significant patterns, relationships, and trends within the data, contributing to a broader understanding of the factors influencing green innovation adoption among manufacturing SMEs in Malaysia. These findings serve as a foundation for the subsequent discussion and interpretation of the research outcomes.

### 4.3.1 Measurement Model Assessment

The PLS-SEM analysis was used to assess the measurement model initially. The outer loadings for each variable were tested. Also, construct reliability and validity served as the two primary criteria for evaluating the measurement model.

The outer loadings of the measurement model indicate the links between observable variables and their associated latent constructs, showing the degree of association for each indicator. Higher outer loading values indicate a stronger link with recommending a minimum threshold of 0.70 (J. Hair et al., 2017). In Table 4.9, all indicators exceeded the threshold, indicating adequate loadings. The lowest value is of formal institutions (FI) indicator 3 with 0.706, while big data analytics capability (BDAC) indicator 4 had the highest value of 0.944. Hence, the reliability of the constructs ensures that the indicators effectively measure the underlying latent variables.

**Table 4.9: Outer Loadings**

| | FI | II | CGD | GC | GDC | OGC | BDAC | GIA |
|---|---|---|---|---|---|---|---|---|
| FI1 | 0.745 | | | | | | | |
| FI2 | 0.721 | | | | | | | |
| FI3 | 0.706 | | | | | | | |
| FI4 | 0.733 | | | | | | | |
| II1 | | 0.721 | | | | | | |
| II2 | | 0.791 | | | | | | |
| II3 | | 0.743 | | | | | | |
| II4 | | 0.842 | | | | | | |
| CGD1 | | | 0.896 | | | | | |
| CGD2 | | | 0.903 | | | | | |
| CGD3 | | | 0.894 | | | | | |
| CGD4 | | | 0.882 | | | | | |
| GC1 | | | | 0.900 | | | | |
| GC2 | | | | 0.878 | | | | |
| GC3 | | | | 0.893 | | | | |
| GC4 | | | | 0.884 | | | | |
| GDC1 | | | | | 0.915 | | | |
| GDC2 | | | | | 0.914 | | | |
| GDC3 | | | | | 0.916 | | | |
| GDC4 | | | | | 0.943 | | | |
| GDC5 | | | | | 0.928 | | | |
| OGC1 | | | | | | 0.902 | | |
| OGC2 | | | | | | 0.904 | | |
| OGC3 | | | | | | 0.927 | | |
| OGC4 | | | | | | 0.935 | | |
| OGC5 | | | | | | 0.912 | | |

| | | |
|---|---|---|
| BDAC1 | 0.927 | |
| BDAC2 | 0.934 | |
| BDAC3 | 0.933 | |
| BDAC4 | 0.944 | |
| BDAC5 | 0.900 | |
| GIA1 | | 0.827 |
| GIA2 | | 0.870 |
| GIA3 | | 0.901 |
| GIA4 | | 0.881 |
| GIA5 | | 0.844 |

Note:
"FI = Formal Institutions, II = Informal Institutions, CGD = Customer Green Demand, GC = Green Competition, GDC = Green Dynamic Capability, OGC = Organisational Green Culture, BDAC = Big Data Analytics Capability, GIA = Green Innovation Adoption"

To obtain convergent validity the construct reliability and average variance extracted (AVE) were evaluated. The construct reliability of the internal consistent construct was tested based on the composite reliability and Cronbach's alpha. The acceptable value for composite reliability should be above 0.70 (J. F. Hair et al., 2019), whereas Cronbach's alpha values must also be 0.70 or more (Irawan et al., 2021). However, it is preferred that Cronbach's alpha should be closer to 1.0 for higher internal consistency reliability (Sekaran & Bougie, 2016). Moreover, the AVE values must be greater than or equal to 0.50 (J. F. Hair et al., 2019). As represented in Table 4.10, the composite reliability for each construct is more than 0.70 and it ranges between 0.817 (formal institutions) to 0.969 (big data analytics capability). Similarly, the AVE was also above 0.50 (shown in Table 4.10). The least AVE was of formal institutions at 52.8%, whereas the uppermost AVE was of big data analytics capability at 86.0%. Overall, each variable in the model proved to be consistently reliable.

**Table 4.10: Construct Reliability and Average Variance Extracted**

| | Composite reliability | Cronbach's alpha | AVE |
|---|---|---|---|
| FI | 0.817 | 0.702 | 0.528 |
| II | 0.857 | 0.779 | 0.601 |
| CGD | 0.941 | 0.916 | 0.799 |
| GC | 0.938 | 0.911 | 0.790 |
| GDC | 0.967 | 0.957 | 0.853 |
| OGC | 0.963 | 0.952 | 0.839 |
| BDAC | 0.969 | 0.959 | 0.860 |
| GIA | 0.937 | 0.916 | 0.748 |

Note:
"FI = Formal Institutions, II = Informal Institutions, CGD = Customer Green Demand, GC = Green Competition, GDC = Green Dynamic Capability, OGC = Organisational Green Culture, BDAC = Big Data Analytics Capability, GIA = Green Innovation Adoption"

Heterotrait-Monotrait (HTMT) ratio was used to test the discriminant validity of the constructs. The threshold value of the HTMT ratio for discriminant validity is below 0.90 (Henseler et al., 2015). Referring to Table 4.11, HTMT ratios for the constructs ranged from 0.035 to 0.599, all of which remained below the threshold of 0.90. Specifically, the highest correlation was observed between organisational green culture (OGC) and green innovation adoption (GIA), with an HTMT value of 0.599. The other notable HTMT values included the relation between green competition (GC) and GIA (0.554) and formal institutions and informal institutions (0.541), which also showed correlations. Overall, the results indicated that the constructs maintained acceptable discriminant validity, supporting the robustness of the measurement model.

**Table 4.11: Heterotrait-Monotrait Ratio (HTMT)**

| | FI | II | CGD | GC | GDC | OGC | BDAC | GIA |
|---|---|---|---|---|---|---|---|---|
| FI | | | | | | | | |
| II | 0.541 | | | | | | | |
| CGD | 0.240 | 0.091 | | | | | | |
| GC | 0.256 | 0.138 | 0.514 | | | | | |
| GDC | 0.124 | 0.044 | 0.114 | 0.110 | | | | |
| OGC | 0.230 | 0.188 | 0.503 | 0.494 | 0.317 | | | |
| BDAC | 0.107 | 0.097 | 0.303 | 0.411 | 0.035 | 0.502 | | |
| GIA | 0.454 | 0.301 | 0.527 | 0.554 | 0.064 | 0.599 | 0.387 | |

Note:
"FI = Formal Institutions, II = Informal Institutions, CGD = Customer Green Demand, GC = Green Competition, GDC = Green Dynamic Capability, OGC = Organisational Green Culture, BDAC = Big Data Analytics Capability, GIA = Green Innovation Adoption"

### 4.3.2 Structural Model Assessment

In terms of the collinearity of the independent variables, the cutoff value for the Variance Inflation Factor (VIF) should not be more than 10 (Sekaran & Bougie, 2016). Table 4.12 shows the smallest VIF value of informal institutions (1.245) and the largest VIF value of green competition (1.652). These results suggest that the constructs are measured reflectively, as the VIF values indicate no problematic multicollinearity among the indicators.

PLS-SEM analysis was performed to evaluate the correlation coefficients between the variables, which is crucial for assessing the structural model, once the measurement model's validity and reliability had been established. The "bootstrapping" method in PLS-SEM was used to get coefficients, t-values, and p-values for the structural model assessment. Levels of significance were determined at 1% (t = 2.57), 5% (t=1.96), and 10% (t =

1.65) (J. F. Hair et al., 2017). Results were deemed unsupported if their p-values were higher than the significance level.

The structural model results indicate the relationships among constructs and their impact on green innovation adoption (GIA). Significant relationships were identified by examining path coefficients, t-statistics, and p-values, with significance levels set at 1%, 5%, and 10% (J. F. Hair et al., 2017). The findings indicate several notable direct, mediated, and moderated effects influencing GIA. Formal institutions (FI) significantly influenced GIA (coefficient = 0.186, t = 3.024, p = 0.003) at the 1% significance level, while informal institutions (II) also showed a significant positive effect on GIA (coefficient = 0.108, t = 1.836, p = 0.066) at the 10% level. Customer green demand had a strong positive influence on GIA (coefficient = 0.195, t = 2.768, p = 0.006), supported at the 1% level, and green competition demonstrated a positive direct effect on GIA (coefficient = 0.158, t = 2.088, p = 0.037), significant at the 5% level.

In terms of mediation, customer green demand influenced GIA through green dynamic capability (GDC) (coefficient = 0.113, t = 2.705, p = 0.007) and green competition influenced GIA through GDC (coefficient = 0.103, t = 3.206, p = 0.001) both were significant at the 1% level of significance. Likewise, green competition influenced GIA through organisational green culture (OGC) (coefficient = 0.030, t = 1.672, p = 0.095) was significant at the 10% level. Conversely, mediation paths from formal and informal institutions through both green dynamic capability and organisational green culture as well as the path from green dynamic capability through organisational green culture, were found

to be unsupported, as their t-values were below 1.65 and p-values exceeded 0.10.

The moderation analysis revealed a significant interaction effect of big data analytic capabilities (BDAC) with green dynamic capabilities on adoption of green innovation (coefficient = 0.132, t = 2.429, p = 0.015) at the 5% significance level. However, the interaction of big data analytic capabilities with organisational green culture although significant but yielded a negative coefficient (coefficient = -0.093, t = 1.670, p = 0.095), so it contradicted the hypothesised positive moderation effect. Therefore, this hypothesis was not supported.

**Table 4.12: Structural Model Results**

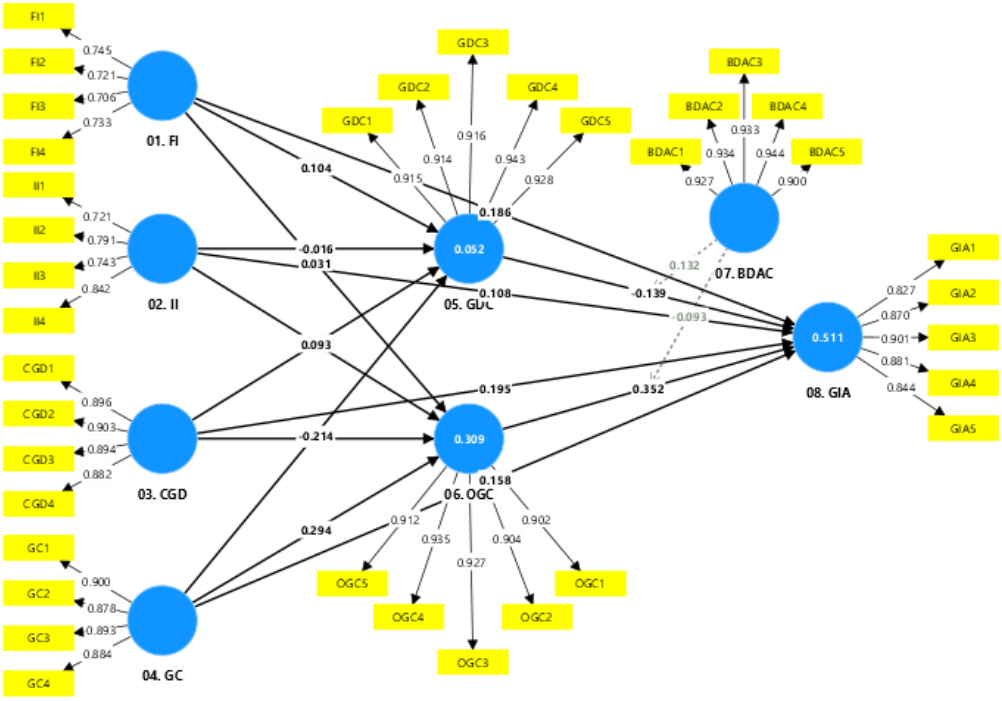
| | | VIF | Coefficient | T statistics | P values | Result |
|---|---|---|---|---|---|---|
| | Direct | | | | | |
| H1a | FI->GIA | 1.282 | 0.186*** | 3.024 | 0.003 | Supported |
| H1b | II->GIA | 1.245 | 0.108* | 1.836 | 0.066 | Supported |
| H2a | CGD->GIA | 1.458 | 0.195*** | 2.768 | 0.006 | Supported |
| H2b | GC->GIA | 1.652 | 0.158** | 2.088 | 0.037 | Supported |
| | Mediation | | | | | |
| H3a | FI->GDC->GIA | - | 0.011 | 0.394 | 0.693 | Unsupported |
| H4a | FI->OGC->GIA | - | -0.014 | 1.123 | 0.261 | Unsupported |
| H3b | II->GDC->GIA | - | 0.033 | 1.212 | 0.226 | Unsupported |
| H4b | II->OGC->GIA | - | 0.002 | 0.193 | 0.847 | Unsupported |
| H3c | CGD->GDC->GIA | - | 0.113*** | 2.705 | 0.007 | Supported |
| H4c | CGD->OGC->GIA | - | -0.026 | 1.535 | 0.125 | Unsupported |
| H3d | GC->GDC->GIA | - | 0.103*** | 3.206 | 0.001 | Supported |
| H4d | GC->OGC->GIA | - | 0.030* | 1.672 | 0.095 | Supported |
| | Moderation | | | | | |
| H5a | BDACxGDC->GIA | - | 0.132** | 2.429 | 0.015 | Supported |
| H5b | BDACxOGC->GIA | - | -0.093 | 1.670 | 0.095 | Unsupported |

Note:
"FI = Formal Institutions, II = Informal Institutions, CGD = Customer Green Demand, GC = Green Competition, GDC = Green Dynamic Capability, OGC =

Organisational Green Culture, BDAC = Big Data Analytics Capability, GIA = Green Innovation Adoption"

1. t = 1.65, P < 0.10*
2. t = 1.96, P < 0.05**
3. t = 2.57, P < 0.01***

**Figure 4.1: Structural Model Results**




The endogenous construct's R-square values of 0.75, 0.50, or 0.25 are characterised as substantial, moderate, and weak, respectively (J. F. Hair et al., 2014, 2017). With an R-square value of 0.511, the model has moderate predictive power for green innovation adoption, implying that the variables account for 51.1% of the variation in GIA. Additionally, the R-square values for other endogenous constructs such as green dynamic capability and organisational green culture are 0.052 and 0.309, respectively, suggesting weak predictive power for green dynamic capability and moderate predictive power for organisational green culture.

Furthermore, the effect of the predictor variable is large at 0.35, medium at 0.15 and small at 0.02 f-square value (J. F. Hair et al., 2014; Tan et al., 2018). Among the other direct variables and predictors, formal institutions and customer green demand show the strongest contribution to green innovation adoption with an effect size (f-square) of 0.055 and 0.054 respectively. Meanwhile, informal institutions and green competition exhibit minimal effects with values of 0.019 and 0.031. The interaction between big data analytic capabilities and green dynamic capabilities demonstrated low effect size (f-square = 0.020), indicating that the combined influence of big data analytic capabilities and green dynamic capabilities on GIA is smaller. Conversely, an interaction between big data analytics capability and organisational green culture also showed a small effect size (f-square = 0.038), suggesting a modest but small combined influence on green innovation adoption.

Lastly, the exogenous constructs have predictive relevance for the endogenous construct in consideration if the Q-square value is larger than 0 (J. F. Hair et al., 2014, 2017; Tan et al., 2018). Hence, the model's predictive relevancy is supported by the Q-squared value of 0.351. In short, the model shows moderate predictive power for green innovation adoption, with significantly lower effect contributions from all the variables supported by established predictive relevancy.

**Table 4.13: R-square, F-square, Q-square**

| Predictors | Outcomes | R-square | Outcome | F-square | Q-square |
|---|---|---|---|---|---|
| FI | GDC | 0.052 | | 0.055 | |
| II | OGC | 0.309 | GIA | 0.019 | 0.351 |
| CGD | GIA | 0.511 | | 0.054 | |

| | |
|---|---|
| GC | 0.031 |
| BDACxGDC | 0.020 |
| BDACxOGC | 0.038 |

Note:
"FI = Formal Institutions, II = Informal Institutions, CGD = Customer Green Demand, GC = Green Competition, GDC = Green Dynamic Capability, OGC = Organisational Green Culture, BDAC = Big Data Analytics Capability, GIA = Green Innovation Adoption"

## 4.4 Conclusion

This Chapter presents the analysis of data collected from 204 responses, analysed using SmartPLS 4. The demographic profiles incorporate respondents' and firms' backgrounds. The measure model assessment using PLS-SEM validated the model's reliability and discriminant validity, followed by structural model assessment providing supported and unsupported hypothesis results along with the model's predictive power. The next chapter will discuss the findings in detail accompanied by the recommendations.

# CHAPTER FIVE

# DISCUSSION AND CONCLUSION

This chapter will provide discussion on the research study findings, implications, limitations, suggestions for future studies along with the conclusion. This chapter begins with descriptive summary of the demographics followed by statistical analysis summary. Subsequently, results for each hypothesis were discussed in detail along with the limitations and suggestions for future research.

## 5.1 Descriptive Summary of the Demographics Analysis

About 66.2% of the respondents were male. 44.1% were aged between 20 to 29 years, whereas 41.2% were having a bachelor's degree. Most of the respondents about 30.9% were from Selangor and 66.7% of the respondents were at the manager/assistant manager level. 19.6% were from machinery and computer equipment. In terms of employment, 53.4% of the firms were having 5 to 75 employees, whereas 46.6% were having 76 to 200 employees fulfilling the manufacturing small and medium-sized enterprises (SMEs) criteria. Lastly, 54.4% of firms had estimated per year revenue between RM15,000,000 to less than RM50,000,000 and 45.6% had RM300,000 to less than RM15,000,000 annual revenue, also meeting the SMEs per year revenue requirement.

## 5.2 Statistical Analysis Summary

Measurement model was tested based on its convergent and discriminant validity. The minimum value for outer loadings was suggested greater than 0.70 (J. F. Hair et al., 2017) which was tested and accomplished. The model's convergent validity was examined by composite reliability, Cronbach's alpha, and average variance extracted (AVE). The convergent validity of all the constructs was achieved by exceeding the adequate value of composite reliability which is 0.70 and the AVE value of greater than 0.50. In this research, formal institutions had the minimum value of composite reliability, Cronbach's alpha, and AVE of 0.817, 0.702, and 0.528 respectively. In terms of discriminant validity, Heterotrait-Monotrait (HTMT) was used to test the latent constructs validity. The threshold value to be achieved for the HTMT ratio is below 0.90 (J. F. Hair et al., 2017; Henseler et al., 2015). The results of the HTMT ratio were satisfactory which means the discriminant validity was achieved and it supports the measurement model.

## 5.3 Hypotheses Testing

Referring to Table 5.1, a total of eight hypotheses were significant (which includes H1a, H1b, H2a, H2b, H3c, H3d, H4d, and H5a) out of fourteen hypotheses. The significant hypotheses H1a, H2a, H3c, and H3d were supported at a 1% level of significance. H2b and H5a were supported at 5% significance level, whereas H1b and H4d were significant at 10%.

**Table 5.1: Summary of the Hypotheses Testing**

| No. | Hypotheses | Results |
|---|---|---|
| 1 | **H1a:** Formal institutions have a positive effect on green innovation adoption in manufacturing SMEs. | Supported (P-value < 0.01) |
| 2 | **H1b:** Informal institutions have a positive effect on green innovation adoption in manufacturing SMEs. | Supported (P-value < 0.10) |
| 3 | **H2a:** Customer green demand positively influences manufacturing SMEs adoption of green innovation. | Supported (P-value < 0.01) |
| 4 | **H2b:** Green competition positively effects manufacturing SMEs' adoption of green innovation. | Supported (P-value < 0.05) |
| 5 | **H3a:** Green dynamic capability mediates the relationship between the formal institutions and the adoption of green innovation. | Not Supported (P-value < 0.10) |
| 6 | **H3b:** Green dynamic capabilities mediate the connection between the informal institutions and the adoption of green innovation. | Not Supported (P-value < 0.10) |
| 7 | **H3c:** Green dynamic capabilities mediate the connection between the customer green demand and the adoption of green innovation. | Supported (P-value < 0.01) |
| 8 | **H3d:** Green dynamic capability mediates the association between the green competition and the adoption of green innovation. | Supported (P-value < 0.01) |
| 9 | **H4a:** Organisational green culture mediates the connection between the formal institutions and the adoption of green innovation. | Not Supported (P-value < 0.10) |
| 10 | **H4b:** Organisational green culture mediates the connection between the informal institutions and the adoption of green innovation. | Not Supported (P-value < 0.10) |
| 11 | **H4c:** Organisational green culture mediates a connection between the customer green demand and adoption of green innovation. | Not Supported (P-value < 0.10) |
| 12 | **H4d:** Organisational green culture mediates the connection between the green competition and the adoption of green innovation. | Supported (P-value < 0.10) |

| | | |
|---|---|---|
| 13 | **H5a:** Big data analytics capability strengthens the connection between green dynamic capabilities and the adoption of green innovation. | Supported (P-value < 0.05) |
| 14 | **H5b:** Big data analytics capability strengthens the connection between organisational green culture and the adoption of green innovation. | Not Supported (P-value < 0.10) |

## 5.4 Answers to Research Questions

The findings of the first research question addressed in Chapter 1 indicate that both formal and informal institutions significantly and positively influence green innovation adoption. Formal institutions, such as regulations, rules, and government policies, create coercive pressures encouraging firms to integrate sustainable practices. Informal institutions, including environmental culture, values, norms, and societal beliefs, also promote adoption by fostering pressure within manufacturing SMEs. These outcomes support institutional theory, demonstrating that institutional environments play a critical role in driving sustainable transitions among Malaysian manufacturing SMEs. Likewise, the results indicate that formal institutions exert a stronger influence on green innovation adoption compared to informal institutions. Regulatory frameworks and government support create direct and enforceable pressures on manufacturing SMEs to implement green practices while informal institutions also positively impact adoption, their effect is comparatively moderate. Therefore, manufacturing SMEs should prioritise formal institutions to drive initial adoption, while gradually strengthening informal institutional alignment to support long-term sustainability transformation.

The results of the second research question confirm that customer green demand and green competition have significant positive associations with green innovation adoption. Customer green demand, representing normative pressure, reflects the growing consumer preference for sustainable products, which motivates manufacturing SMEs to adopt eco-friendly practices. While, green competition, representing mimetic pressure, compels manufacturing SMEs to replicate successful green strategies implemented by competitors. Together, these forces highlight the market's instrumental role in accelerating sustainability transitions.

Thirdly, according to the third research question, the study confirms that internal organisational factors partially mediate these relationships. Green dynamic capability mediates the relationship between green competition and green innovation adoption, while organisational green culture mediates between market environment variables and adoption. These mediating mechanisms underscore the importance of strengthening internal competencies to effectively translate external pressures into actionable innovation strategies.

Lastly, the findings for the fourth research question reveal that big data analytics capabilities significantly moderate the relation between green dynamic capabilities and green innovation adoption among Malaysian manufacturing SMEs. However, the moderating effect is less pronounced for organisational green culture. This implies that while technological capabilities enhance resource optimisation and strategic alignment, cultural transformation may require more than technological support such as leadership commitment and

value internalisation to support the green innovation adoption among manufacturing SMEs in Malaysia.

## 5.5 Findings Discussion

### 5.5.1 Formal Institutions and Adoption of Green Innovation

**H1a:** Formal institutions have a positive effect on green innovation adoption in manufacturing SMEs.

Formal institutions (FI) exert a significant influence on manufacturing SMEs' adoption of green innovation due to pressure from regulatory bodies (DiMaggio & Powell, 1983; Yang et al., 2019). This study demonstrated that formal institutions have a positive and significant impact on green innovation adoption (GIA), with H1a supported at a significance level of 1%, showing a coefficient of 0.186. The findings are aligned with institutional theory, indicating that coercive pressure from formal institutions compels manufacturing SMEs to prioritise proactive environmental practices that align with sustainability objectives (Thomas et al., 2021).

The current study results are consistent with the past studies. For example, Balzano et al. (2024) argue that formal institutions not only shape environmental strategies but also help standardise sustainable behaviours across manufacturing SMEs, especially in regulated markets. Similarly, Z. Chen and Liang (2023) suggest that regulatory mechanisms foster green transformation, provided the institutional environment includes policies alongside compliance

pressures. According to the Monash-Alliance ESG 2.0 Report (2025), 69% of manufacturing SMEs in Malaysia have adopted ESG practices up from 28% in prior years largely due to heightened regulatory scrutiny and alignment with the National Industrial Master Plan (NIMP) 2030. Furthermore, 80% of SMEs now report awareness of ESG principles, compared to just 14% two years ago, highlighting the role of state-led initiatives in shaping environmental behaviour (Monash-Alliance ESG 2.0 Report, 2025).

However, the increased ESG uptake does not necessarily translate to innovation. Past literature cautions that such regulatory frameworks often result in symbolic compliance rather than substantive green innovation (Shahzad et al., 2023). SMEs, especially resource-constrained ones, may adopt minimal practices to avoid penalties while lacking the capacity or motivation to innovate beyond legal requirements (Lestari & Sunyoto, 2023). Additionally, according to the news agency, the Malaysian government's intensified enforcement, such as crackdowns in the palm oil industry to comply with the EU Deforestation Regulation, further exemplifies the pressure to align with global sustainability standards (Reuters, 2025). These findings suggest that while formal institutions play a critical role in driving the initial adoption of green practices, they may not sufficiently incentivise transformative environmental innovation unless coupled with support mechanisms such as subsidies, policies, knowledge sharing, or capacity building (X. Lin & Su, 2024).

### 5.5.2 Mediating Role of Green Dynamic Capability Between Formal Institutions and Green Innovation Adoption

**H3a:** Green dynamic capability mediates the relationship between the formal institutions and the adoption of green innovation.

This study's findings indicate that green dynamic capability (GDC) does not significantly mediate the connection between formal institutions and the adoption of green innovation among manufacturing SMEs, as evidenced by a p-value of 0.693, which renders the hypothesis (H3a) does not support at the 10% significance level. The results were against the past study literature (X. Lin & Su, 2024). Although formal institutions, such as regulatory bodies and government policies, are often theorised to influence manufacturing SMEs toward sustainable innovation (Z. Huang & Xiao, 2023; X. Lin & Su, 2024), the absence of significant mediation in this context suggests that formal pressures alone may not effectively translate into the development of green dynamic capabilities, which are essential for sustained environmental innovation (Teece, 2007).

While the Malaysian government has made considerable efforts to raise awareness and institutionalise sustainability through initiatives such as the Green Technology Master Plan (GTMP), MyHIJAU Mark, and the SME Sustainability Roadmap, the actual adoption of green technologies and innovation practices among manufacturing SMEs remains low (Yacob et al., 2022). For example, Shahzad et al. (2023) note that only 30% of SMEs have

adopted green technologies, despite increasing policy support and awareness campaigns. Similarly, SME Corp. Malaysia (2024) reported that only 26% of SMEs are aware of integrated sustainability-focused innovations into their operations, largely due to capability limitations.

This finding is consistent with prior research, which emphasises that formal institutions often create pressure for compliance but lack the awareness and support needed to enhance manufacturing SMEs' internal competencies (Shahzad et al., 2023). The absence of dynamic capability development may be attributed to limited organisational resources, lack of tailored support, and insufficient absorptive capacity among SMEs to interpret and act on institutional signals (Lestari & Sunyoto, 2023).

### 5.5.3 Mediating Effect of Organisational Green Culture Between Formal Institutions and Green Innovation Adoption

**H4a:** Organisational green culture mediates the connection between the formal institutions and the adoption of green innovation.

This study's outcome indicates that organisational green culture (OGC) does not significantly mediate the association between formal institutions and the adoption of green innovation in manufacturing SMEs, because the hypothesis (H4a) does not support due to the greater p-value than the 10% significance level threshold. This suggests that while FI, such as environmental regulations, standards, and policies, are crucial drivers of green practices, they

may not directly foster an organisational green culture that supports innovation among manufacturing SMEs. Institutional theory posits that formal institutions can exert pressure on organisations to comply with sustainability norms (DiMaggio & Powell, 1983). However, the absence of significant mediation here suggests that regulatory pressures alone may not be sufficient to embed green values within the organisational culture of manufacturing SMEs, which is essential for continuous and proactive innovation (Dangelico & Pujari, 2010).

This finding aligns with recent literature indicating that although FI create a compliance framework for green practices, internal cultural elements may require additional drivers to effectively support green innovation in manufacturing SMEs. For example, Z. Chen and Liang (2023) argue that while regulations can prompt initial green activities, a deeper organisational culture committed to sustainability often emerges through leadership engagement and intrinsic values rather than external mandates alone. Similarly, Subramanian and Suresh (2023) found that cultural support for green innovation is more likely to develop when manufacturing SMEs engage in practices that go beyond mere compliance, integrating sustainability into their core values through management support. This no mediation effect highlights the complex relationship between external institutional pressures and internal cultural transformation, suggesting that for formal institutions to effectively promote green innovation in manufacturing SMEs, they may need to be paired with internal, values-driven initiatives that cultivate an organisational green culture.

### 5.5.4 Informal Institutions and Adoption of Green Innovation

**H1b:** Informal institutions have a positive effect on green innovation adoption in manufacturing SMEs.

This study explored the role of informal institutions (II) in the adoption of green innovation and found a positive and significant relationship between the two, as indicated by a coefficient of 0.108 and a p-value of 0.066, supporting the hypothesis (H1b) at the 10% significance level. This indicates that norms, values, and cultural attitudes play a meaningful role in shaping the sustainability behaviour of manufacturing SMEs in Malaysia. According to institutional theory, informal institutions influence organisational actions through shared beliefs and societal expectations (Z. Chen & Liang, 2023). In supportive social contexts where environmental values are internalised, manufacturing SMEs are more likely to align their innovation strategies with sustainability goals (T. Liu et al., 2023).

Recent empirical studies confirm this relationship. Guo et al. (2024) emphasised that societal pressure and environmental awareness embedded in informal networks promote green behaviour in Chinese firms. Similarly, Makhloufi (2024) found communities that prioritise sustainability create an enabling environment for eco-innovation adoption. These results align with the growing understanding that social legitimacy, derived from community expectations, drives firms toward adopting environmentally responsible practices.

Conversely, in contexts where environmental awareness is lacking, such as in regions where green practices are not normalised, informal institutions may act as a barrier. For instance, Indrawati et al. (2023) found that in Indonesia, the adoption of green innovation among SMEs is significantly influenced by organisational factors, including the prevailing cultural attitudes towards sustainability. Their study suggests that in areas where environmental concerns are not deeply embedded in the organisational culture, SMEs may be less inclined to adopt green innovations substantively.

### 5.5.5 Mediating Effect of Green Dynamic Capability Between Informal Institutions and Green Innovation Adoption

**H3b:** Green dynamic capabilities mediate the connection between the informal institutions and the adoption of green innovation.

This study's findings reveal that green dynamic capabilities do not significantly mediate the relationship between informal institutions and the adoption of green innovation in manufacturing SMEs, as an indicated hypothesis (H3b) does not support and a p-value falls above the 10% significance threshold. The findings were against the past literature (S. K. Singh et al., 2022). Informal institutions, representing societal norms, cultural expectations, and community values are often theorised to foster voluntary compliance and proactive environmental behaviour (Aslam, 2022). However, the current study finding suggests that these pressures, while potentially

influential in shaping organisational intent, are insufficient to translate into the internal dynamic capabilities necessary for implementing green innovation.

In the Malaysian context, while sustainability is increasingly featured in public discourse and business platforms, recent studies reveal that the actual adoption of green practices among SMEs remains low (Shahzad et al., 2023). According to Yacob et al. (2022) limited manufacturing SMEs have incorporated environmental management systems or engaged in structured green innovation activities. It reflects a broader disconnect between growing societal awareness and the internalisation of such norms into business capabilities particularly in resource-constrained manufacturing SMEs. Without formal technical training or support, many manufacturing SMEs are unable to develop the necessary green dynamic capabilities, even if informal pressures exist (Yu et al., 2022).

Moreover, X. Lin and Su (2024) emphasise that informal institutions can promote an initial awareness of sustainability but are often inadequate for developing specific green capabilities, which tend to require additional internal or external support such as customer demand, competitive incentives, or resource allocation (Yu et al., 2022). Consequently, informal institutions alone may not successfully drive the capability-building efforts required for large green innovation uptake in manufacturing SMEs, suggesting that policy or more structured initiatives or resource-based interventions necessary to enhance these green dynamic capabilities (Z. Chen & Liang, 2023).

### 5.5.6 Mediating Effect of Organisational Green Culture Between Informal Institutions and Green Innovation Adoption

**H4b:** Organisational green culture mediates the connection between the informal institutions and the adoption of green innovation.

This study's results reveal that organisational green culture does not significantly mediate a relation between informal institutions and the adoption of green innovation, as hypothesis (H4b) was not supported because the p-value was greater than 10% significance level. This suggests that while II such as societal norms, industry standards, and stakeholder expectations can influence manufacturing SMEs toward green practices, they may not be sufficient to foster a deeply ingrained green culture that drives green innovation. Institutional theory explains that informal institutions shape organisational behaviour through norms and expectations rather than regulations (Ji et al., 2019). However, the absence of significant mediation implies that such informal pressures alone may not embed sustainability deeply enough within an organisational culture to lead to systematic innovation in green practices among manufacturing SMEs.

This finding aligns with recent studies, which indicate that while informal institutions can encourage sustainability efforts, a supportive organisational culture often requires additional internal factors to effectively translate these informal pressures into innovation in manufacturing SMEs. For example, Y. Li et al. (2019) found that stakeholder expectations alone may

encourage environmental practices, but a green culture typically requires internal commitment from leadership and a shared organisational vision of sustainability. Furthermore, Lestari and Sunyoto (2023) argue that informal pressures may initiate environmental action but sustaining it through eco-innovation necessitates a strong organisational culture in SMEs that values and supports continuous learning and adaptation. These findings suggest that the role of informal institutions in promoting GIA may be limited without a proactive green culture within the organisation, underscoring the need for manufacturing SMEs to cultivate internal cultural support alongside responding to external, informal pressures.

### 5.5.7 Customer Green Demand and Adoption of Green Innovation

**H2a:** Customer green demand positively influences manufacturing SMEs' adoption of green innovation.

This study examined the effect of customer green demand (CGD) on the adoption of green innovation within manufacturing SMEs, revealing a positive and significant relationship, with a coefficient of 0.195 and a p-value of 0.006, thus supporting the hypothesis (H2a) at the 1% significance level. According to institutional theory, customer demands and expectations serve as a form of external pressure that compels manufacturing SMEs to conform to socially valued practices, including green innovation (DiMaggio & Powell, 1983). When customers demonstrate a preference for environmentally sustainable products, manufacturing SMEs are more likely to adopt green innovation to

maintain their market relevance, reputation, and customer loyalty (Z. Chen & Liang, 2023). The finding of the previous studies suggests that heightened customer demand for green products acts as an institutional isomorphism, motivating manufacturing SMEs to prioritise eco-friendly practices and innovations as a response to this external stakeholder pressure (Barragán-Hernández & Aguilar-Fernández, 2024).

The findings align with Barragán-Hernández and Aguilar-Fernández (2024) research indicating that customer demand play a significant role in driving manufacturing SMEs' environmental strategies. For example, Y. Li et al. (2019) found that customer demand for green products positively influences the adoption of green innovation, as firms seek to meet these expectations to gain competitive advantage. Additionally, Cai and Li (2018) observed that companies facing high levels of customer pressure to act sustainably are more likely to innovate their processes and products to align with customer values on sustainability. In line with this, Lestari and Sunyoto (2023) emphasise that customer pressure can lead to substantial changes in organisational practices, particularly in environmentally sensitive manufacturing SMEs where green demand is high.

These findings underscore the importance of customer green demand in promoting sustainable business practices. As manufacturing SMEs seek to satisfy this demand, they are more likely to invest in green innovations that reduce environmental impact, enhancing their market competitiveness while contributing to broader sustainability goals.

### 5.5.8 Mediating Effect of Green Dynamic Capability Between Customer Green Demand and Green Innovation Adoption

**H3c:** Green dynamic capabilities mediate the connection between the customer green demand and the adoption of green innovation.

The findings of this study indicate that green dynamic capabilities partially mediate the relationship between customer green demand and the adoption of green innovation among manufacturing SMEs, as the hypothesis (H3c) was supported by a coefficient of 0.113 and a p-value of 0.007 at the 1% significance level. This outcome aligns with dynamic capability theory (Teece, 2007), which emphasises that firms must develop internal capabilities to sense, seize, and transform in response to external environmental changes. In the context of SMEs, increasing customer awareness and demand for green products push firms to build adaptive capabilities that enable them to innovate sustainably (Z. Chen & Liang, 2023).

These findings were aligned with the earlier research (Sun et al., 2024). Sun et al. (2024) show that customer-driven green demand, when combined with strong organisational learning mechanisms and environmental strategies, contributes to the development of dynamic capabilities that enhance green innovation performance. Furthermore, Xiao et al. (2023) and Yousaf (2021) emphasise that SMEs actively responding to green consumerism often develop

new routines and capabilities to meet sustainability expectations, which reinforces innovation adoption.

Moreover, recent empirical evidence shows that green customer demand increasingly shape firms' innovation agendas, particularly in the manufacturing sector where product environmental performance is scrutinised (Z. Chen & Liang, 2023). As a result, SMEs that successfully leverage green dynamic capability can proactively engage in eco-innovation and maintain competitive advantage through sustainability-driven differentiation.

### 5.5.9 Mediating Effect of Organisational Green Culture Between Customer Green Demand and Green Innovation Adoption

**H4c:** Organisational green culture mediates a connection between the customer green demand and adoption of green innovation.

This study's outcomes reveal that organisational green culture does not mediate the relation between customer green demand and adoption of green innovation among manufacturing SMEs, with the hypothesis (H4c) not supported at the 10% significance level. This suggests that as customer demand for environmentally friendly products may exert external pressure on firms, they do not automatically lead to the formation of a green organisational culture that facilitates innovation within SMEs. According to institutional theory (DiMaggio & Powell, 1983), customer demand can act as a normative pressure shaping firms' strategic orientation. However, the insignificant mediation effect

suggests that manufacturing SMEs may not be effectively translating this pressure into cultural and organisational practices supportive of green innovation. This could be due to limited managerial commitment, resource constraints, or the absence of sustainability as a core organisational value (Afum et al., 2020; Akpa et al., 2021).

This finding diverges from earlier studies that emphasise the enabling role of organisational green culture in driving green innovation. For example, X. Liu and Lin (2020) found that environmentally conscious customers could influence firms to internalise green values, thereby fostering a culture conducive to sustainability-driven innovation. Similarly, Imran et al. (2021) and Y. Li et al. (2019) highlighted that organisational culture functions as a mediating mechanism through which market pressures translate into innovation outcomes. However, such cultural transformation often requires deliberate leadership efforts, structured training, and long-term value alignment factors that many SMEs might lack (Z. Chen & Liang, 2023).

In the context of this study, the absence of a mediating effect implies that external green demand alone is insufficient to cultivate an organisational culture that fosters green innovation. Manufacturing SMEs may require additional internal mechanisms such as green leadership, employee engagement, and sustainability training to embed green values into their culture and enable effective innovation responses to customer demands.

### 5.5.10 Green Competition and Adoption of Green Innovation

**H2b:** Green competition positively effects manufacturing SMEs' adoption of green innovation.

This study explored the influence of green competition (GC) on manufacturing SMEs' adoption of green innovation, revealing a positive and significant relationship, as evidenced by a coefficient of 0.158 and a p-value of 0.037, thus supporting the hypothesis (H2b) at the 5% significance level. This finding aligns with institutional theory, which posits that competitive pressures act as drivers for organisations to adopt norms and practices that provide legitimacy and competitive advantage within their industries (DiMaggio & Powell, 1983). In response to competitive pressures, manufacturing SMEs may feel compelled to adopt green innovation to align with or outpace the environmental initiatives of their competitors, ensuring their relevance in the market and appealing to a more environmentally conscious consumer base (Barragán-Hernández & Aguilar-Fernández, 2024).

The results of this study are consistent with Barragán-Hernández and Aguilar-Fernández (2024) indicating that manufacturing SMEs facing strong competition are more likely to adopt sustainable practices as a means of differentiation and market positioning. For instance, Rodrigues and Franco (2023) found that competition fosters green innovation as manufacturing SMEs seek to strengthen their brand by demonstrating a commitment to environmental sustainability. Similarly, Maniu et al. (2021) observed that competitive pressure

from green leaders can push other manufacturing SMEs within an industry to adopt green innovation, ultimately raising the environmental standards of the entire sector. This competitive drive among manufacturing SMEs to adopt green practices is particularly significant in industries where consumers are increasingly sensitive to environmental impact, thereby positioning green competition as a catalyst for green innovation.

Moreover, green competition not only serves as a performance-enhancing strategy but also enables manufacturing SMEs to build a more resilient and sustainable business model. As manufacturing SMEs embrace green innovation in response to competitive pressure, they contribute to a broader shift towards sustainability across the industry, creating a competitive but collaborative push towards environmental responsibility.

### 5.5.11 Mediating Effect of Green Dynamic Capability Between Green Competition and Green Innovation Adoption

**H3d:** Green dynamic capability mediates the association between the green competition and the adoption of green innovation.

The findings of this study indicate that green dynamic capability partially mediates the relationship between green competition and the adoption of green innovation in manufacturing SMEs. With a p-value of 0.001, the hypothesis (H3d) is supported at the 1% significance level, suggesting that manufacturing SMEs facing competitive pressures to adopt environmentally

friendly practices are more likely to develop the necessary dynamic capabilities to enable effective green innovation. This aligns with dynamic capability theory, which posits that competitive pressures serve as external triggers that prompt firms to develop adaptive capabilities, allowing them to respond to environmental changes and stakeholder expectations (Teece, 2007). Institutional theory also supports this by suggesting that competitive pressures push firms to align with prevailing environmental norms, further strengthening their commitment to sustainable innovation (Z. Chen & Liang, 2023).

The significant mediation effect of green dynamic capabilities implies that competition in green practices does not merely push firms toward green innovation; it fosters the development of critical organisational capabilities that enhance a manufacturing SMEs ability to innovate sustainably. Recent studies echo this by highlighting the role of competitive pressures in fostering dynamic capabilities that support environmental strategies. For example, X. Lin and Su (2024) found that competitive forces drive manufacturing firms to innovate by developing capabilities in environmental technology, adaptive resource allocation, and knowledge management to meet industry benchmarks. Similarly, Z. Chen and Liang (2023) suggest that green competition encourages manufacturing firms to build internal capacities to differentiate themselves sustainably. This mediation effect underscores the importance of green competition as a catalyst that both motivates and enables manufacturing SMEs to incorporate sustainable practices, suggesting that manufacturing SMEs can benefit from embracing competitive pressures as opportunities to build green dynamic capabilities for long-term sustainability.

### 5.5.12 Mediating Effect of Organisational Green Culture Between Green Competition and Green Innovation Adoption

**H4d:** Organisational green culture mediates the connection between the green competition and the adoption of green innovation.

The results of this research indicate that organisational green culture partially mediates a relationship between green competition and the adoption of green innovation in manufacturing SMEs, as the hypothesis (H4d) is supported at a 10% significance level (p-value = 0.095). This suggests that manufacturing SMEs facing competitive pressures to adopt sustainable practices often embed green values into their culture, which in turn drives green innovation. According to institutional theory, competitive pressures serve as external forces that push organisations to adopt practices aligning with societal and market expectations for environmental sustainability (DiMaggio & Powell, 1983). In this case, green competition catalyzes the development of an internal green culture that acts as an enabler, allowing manufacturing SMEs to turn competitive pressures into sustainable innovation initiatives.

This finding aligns with recent studies indicating that GC can drive green innovation in manufacturing SMEs, especially when supported by an organisational culture committed to sustainability. For instance, Shahzad et al. (2023) encourage GC in manufacturing SMEs to prioritise environmental values and practices, but internalisation through an established green culture is

essential for these initiatives to translate into innovative, sustainable products and practices. When manufacturing firms integrate green culture as part of their strategic response to competition, they can achieve a competitive advantage by meeting external market demands for sustainability while driving internal innovation efforts in the environmental domain (Cai & Li, 2018).

### 5.5.13 Moderating Effect of Big Data Analytics Capability Between

#### 5.5.13.1 Green Dynamic Capabilities and Green Innovation Adoption

**H5a:** Big data analytics capability strengthens the connection between green dynamic capabilities and the adoption of green innovation.

The findings of this study confirm that big data analytics capabilities (BDAC) significantly and positively moderate the relationship between green dynamic capabilities and the adoption of green innovation among manufacturing SMEs in Malaysia. With a path coefficient of 0.132 and a p-value of 0.015, the hypothesis (H5a) is supported at the 5% significance level. This suggests that the presence of big data analytics capabilities enhances the positive influence of green dynamic capabilities on green innovation adoption reinforcing the idea that advanced data capabilities enable manufacturing SMEs to better sense, seize, and reconfigure resources in alignment with green innovation objectives. This result aligns with the dynamic capability theory (Teece, 2007), which emphasises that manufacturing SMEs equipped with technological tools such as big data analytics capabilities can better translate environmental sensing and learning (core functions of green dynamic

capability) into actionable and sustainable innovations (Yu et al., 2022). Prior studies have highlighted that BDAC empowers manufacturing SMEs to analyse real-time market and environmental data, predict customer trends, and adjust innovation strategies effectively (Loh & Teoh, 2021), thereby amplifying the impact of green dynamic capability on green innovation outcomes.

Furthermore, this finding is consistent with Malaysia's current trajectory toward digital transformation. According to the leading financial news agency, the big data analytics market in Malaysia is projected to grow from US$1.1 billion in 2021 to US$1.9 billion by 2025, indicating a robust national momentum towards digitalisation in the manufacturing sector (The Edge Malaysia, 2022). Additionally, Malaysia recorded RM163.6 billion in digital investments in 2024, a significant increase from RM46.8 billion in 2023 (The Edge Malaysia, 2025), reflecting strong national momentum towards digitalisation among manufacturing SMEs.

Overall, this study contributes to the literature by extending the discussion on the role of BDAC as a critical moderator that enhances the impact of existing green dynamic capabilities on green innovation among Malaysian manufacturing SMEs.

#### 5.5.13.2 Organisational Green Culture and Green Innovation Adoption

**H5b:** Big data analytics capability strengthens the connection between organisational green culture and the adoption of green innovation.

This study's findings indicate that big data analytics capability does not significantly moderate the relationship between organisational green culture and the adoption of green innovation among manufacturing SMEs, as the hypothesis (H5b) was not supported at the 10% significance level. This suggests that while BDAC is theorised to enhance innovation by enabling data-driven insights and strategic decision-making (Al-Khatib, 2022), its influence on the connection between green culture and adopting innovations remains limited in this context. This result challenges assumptions derived from organisational cultural theory, which posit that technological capabilities such as big data analytics capabilities could amplify the effectiveness of a green culture by providing the analytical foundation to translate values and practices into actionable green innovations among manufacturing SMEs.

This finding contrasts with much of the existing literature, which emphasises the role of big data analytics capabilities in facilitating innovation. For instance, Dubey et al. (2019) suggest that big data analytics capabilities enhance organisational culture by embedding data-driven decision-making processes, which should ideally align with sustainability goals. Similarly, Bag et al. (2020) argue that big data analytics capabilities strengthens the integration of cultural and operational dimensions for green innovation. However, the lack of significant moderation found in this study may indicate that, despite having access to advanced data analytics capabilities, organisations may fail to align these tools effectively with the broader cultural values needed to drive innovation.

Additionally, implementation challenges such as a lack of expertise, high costs, or resistance to change within the organisation might explain this discrepancy among manufacturing SMEs (Gen et al., 2022). Manufacturing SMEs, often constrained by limited resources, may struggle to integrate big data analytics capabilities into their organisational processes in a way that complements their green culture. Resistance to adopting new technologies, particularly among employees accustomed to traditional decision-making approaches, could also hinder the effective use of big data analytics capabilities (Shahzad et al., 2023) to strengthen green innovation efforts. Furthermore, high implementation and maintenance costs associated with advanced analytics tools may limit their utilisation in resource-constrained manufacturing SMEs, diverting attention away from aligning these tools with sustainability goals. These challenges underscore the complexity of integrating big data analytics capabilities into the green innovation process within manufacturing SMEs. While big data analytics capabilities have the potential to enhance organisational decision-making and support sustainability efforts, its effectiveness in driving green innovation is contingent upon overcoming resource limitations, technological barriers, and organisational resistance.

## 5.6 Implications of the Study

This study aims to investigate the effect of institutional and market environment on GIA among Malaysian manufacturing SMEs, mediated by internal organisation factors (green dynamic capability and organisational green

culture), and moderated by big data analytics capability (BDAC). The contributions of the research are as follows.

### 5.6.1 Practical Implications

The findings of this study offer several practical implications for policymakers, SME owners, and other stakeholders seeking to accelerate the adoption of green innovation in manufacturing SMEs. The direct effect indicates that formal institutions (FI), informal institutions (II), customer green demand (CGD), and green competition (GC) have a significant influence on GIA. This highlights the importance of a supportive institutional environment and growing market pressures in driving sustainable transitions. Policymakers in Malaysia particularly those operating under the Malaysian green technology and climate change corporation (MGTC), SME Corporation, and the ministry of investment, trade and industry (MITI) should continue to strengthen both regulatory and incentive-based frameworks to promote eco-innovation. Strengthening formal institutions through environmental laws, tax relief for eco-innovation, and funding schemes for sustainable manufacturing can directly motivate manufacturing SMEs to pursue green innovation. This can be achieved by expanding the green technology financing scheme (GTFS), introducing tax incentives and R&D subsidies for eco-innovative projects, and reinforcing environmental management certifications such as ISO 14001 or the low carbon cities framework. Likewise, reinforcing informal institutions such as social norms and cultural expectations regarding environmental responsibility can

further shape the values and behaviours of manufacturing SMEs in favour of sustainability.

From a market-driven perspective, the strong influence of the market environment on green innovation adoption underscores the role of external stakeholder pressure. Customers increasingly demand environmentally responsible products and competitive pressures push Malaysian manufacturing SMEs to differentiate themselves through green innovation. Malaysian manufacturing SMEs managers should proactively respond to these pressures by investing in product redesign, adopting cleaner production technologies, and communicating their green initiatives to environmentally conscious consumers. Manufacturing SMEs in Malaysia that recognise and strategically respond to these market dynamics are more likely to sustain competitive advantage in green-oriented markets.

The mediation analysis reveals that green dynamic capability (GDC) significantly mediates the relationships between the market environment and GIA. This suggests that external drivers must be complemented by internal dynamic capabilities that enable Malaysian manufacturing SMEs to adapt, reconfigure, and apply green knowledge in their innovation processes. Malaysian manufacturing SME owners should therefore prioritise the development of green dynamic capability by fostering organisational learning, cross-functional collaboration, and resource reallocation aimed at green objectives. Capacity-building programs, sustainability training, and the integration of environmental KPIs can enhance Malaysian manufacturing

SMEs' ability to respond to evolving green demands through innovation. Interestingly, organisational green culture (OGC) shows a significant mediating effect between green competition and GIA. This implies that cultivating a green organisational culture can support manufacturing SMEs in Malaysia in responding to competitive sustainability pressures, though it may not be sufficient as a stand-alone mechanism for the broader adoption of green innovation. However, not all mediating effects were significant. For instance, certain paths involving GDC and OGC were not supported, indicating that while internal factors are important, many Malaysian SMEs may lack the maturity, resources, or digital capacity required to convert external pressures into sustained innovation outcomes. These non-significant results highlight the need for institutional support that goes beyond policy incentives to include the development of environmental leadership, employee training, and green knowledge-sharing networks in Malaysian manufacturing SMEs.

The moderation analysis shows that big data analytics capabilities strengthen the effect of green dynamic capabilities on GIA, reinforcing the role of digital tools in enabling dynamic green capabilities among manufacturing SMEs in Malaysia. This suggests that when SMEs in Malaysia possess both the ability to adapt green strategies (GDC) and the technological infrastructure to monitor and interpret sustainability data (BDAC), they are more likely to adopt green innovation successfully. Therefore, Malaysian manufacturing SME managers should invest in data analytics tools tailored to track environmental performance indicators, energy use, emissions, and compliance metrics. Policymakers and industrial development associations in Malaysia such as

Malaysia digital economy corporation (MDEC) and MGTC can support this alignment by providing grants and training programs specifically designed to build analytical skills related to environmental data management.

Lastly, this study contributes to SDG 9 (Industry, Innovation, and Infrastructure) by highlighting the role of institutional and market drivers in shaping green innovation trajectories, and to SDG 12 (Responsible Consumption and Production) by demonstrating how consumer pressure and sustainable competition can foster greener practices in manufacturing SMEs. The insights from this study can guide national and regional efforts to mainstream eco-innovation in industrial policy and encourage manufacturing SMEs to play a more active role in sustainable development.

### 5.6.2 Theoretical Implications

The findings of this study contribute to the institutional theory by demonstrating the nuanced effects of coercive, mimetic, and normative pressures on green innovation in manufacturing SMEs. Coercive pressures, represented by formal and informal institutions, were found to drive compliance with environmental norms but lacked a significant influence in fostering green dynamic capabilities and internal green culture that mediates GIA. This highlights the limitation of relying solely on regulatory and social pressures to embed sustainability within organisational practices in manufacturing SMEs. Mimetic isomorphism, reflected in green competition, proved to be a significant driver of green innovation by fostering both green dynamic capability and

organisational green culture. This underscores the role of competitive pressures in motivating manufacturing SMEs to emulate best practices and differentiate themselves sustainably. Normative isomorphism, represented by customer green demand, was also found to promote green innovation through its influence on green dynamic capabilities, but failed through organisational green culture. These findings reinforce the role of external forces in shaping green innovation pathways, while also highlighting the varying effectiveness of different isomorphic pressures in cultivating internal organisational factors.

The application of dynamic capability theory in this study provides novel insights into the interaction between green dynamic capabilities, big data analytics capabilities, and GIA in manufacturing SMEs. The findings reinforce the theoretical assertion that dynamic capabilities are essential for firms to reconfigure internal competencies in response to environmental changes. Specifically, green dynamic capability emerges as a critical mediating mechanism between green competition and GIA, indicating that manufacturing SMEs must build adaptive capacities to effectively translate competitive sustainability pressures into innovative green outcomes. Importantly, the study finds that big data analytics capabilities positively moderates the relationship between green dynamic capabilities and GIA, suggesting that manufacturing SMEs with higher levels of big data analytics capabilities are better able to leverage their dynamic capabilities for sustainable innovation. This synergy highlights the value of integrating advanced data analytics into strategic and operational decision-making processes to enhance the agility, responsiveness, and environmental adaptability of manufacturing SMEs.

In terms of organisational cultural theory, organisational green culture mediate the relationships between green competition and green innovation adoption. The findings indicate that a robust green culture significantly mediates the impact of green competition on GIA, highlighting its importance as an internal enabler of sustainability-driven innovation in manufacturing SMEs. However, the lack of mediation effects between formal and informal institutions and GIA suggests that external pressures alone may not be enough to incorporate green values within manufacturing SMEs. Similarly, the moderation effect of big data analytics capabilities does not support the relationship between organisational green culture and GIA, which highlights that the lack of expertise, higher cost, and resistance to change hinder manufacturing SMEs from moving towards sustainability internally. These results suggest that green culture must be cultivated proactively through internal leadership, shared values, and integration with operational practices, rather than relying solely on external pressures. By demonstrating the critical role of an organisational green culture in translating external competitive pressure into actionable innovation strategies, this study extends the theoretical understanding of how internal cultural dynamics interact with external competitive forces to drive green innovation in manufacturing SMEs.

## 5.7 Limitations and Recommendations for Future Research

Despite its valuable contributions to the understanding of green innovation adoption, this study has several limitations that must be

acknowledged, alongside recommendations for future research to address these constraints.

Firstly, the primary limitation pertains to the depth of the research on the adoption of green innovation among Malaysian manufacturing SMEs. The study exclusively employed a quantitative method, focusing on survey data to analyse the relationships among institutional and market environments, internal organisational factors, and green innovation adoption. Future research could benefit from incorporating both qualitative and quantitative methods. While this study relied on survey data, a mixed-methods approach, including interviews or case studies, could provide deeper insights into the nuanced factors influencing green innovation adoption in manufacturing SMEs. Qualitative data would allow for a richer exploration of organisational culture, managerial perspectives, and sector-specific challenges.

Additionally, the cross-sectional nature of the research limited the timeframe for data collection, making it challenging to capture the evolving dynamics of green innovation adoption over time. To overcome the limitations of a cross-sectional design, future studies should consider adopting a longitudinal approach. This would allow researchers to track changes in green innovation adoption over time, providing a more comprehensive understanding of the evolving dynamics in green innovation adoption and the role of external and internal aspects that influence eco-innovation adoption at different stages.

Another limitation is the exclusive focus on the manufacturing sector, which limits the generalisability of the findings to other industries. While the study focused on manufacturing SMEs, it did not explore other sectors such as construction, retail, or healthcare, each of which may face unique challenges and opportunities in adopting green innovation. These sectors may have different regulatory pressures, technological needs, or market demands that affect how green innovation is adopted and implemented. Therefore, the findings cannot be applied to large organisations or industries outside of manufacturing, where adoption dynamics could differ significantly. Future research should expand to include multiple sectors that would offer a more nuanced understanding of GIA. Investigating industries such as construction, retail, healthcare, and others would allow for a comparative analysis of the adoption patterns, challenges, and strategies specific to each sector. Sector-specific studies would help identify industry-specific drivers and barriers to green innovation and enable tailored recommendations for each sector. Moreover, future research should investigate the role of large organisations in driving or hindering green innovation. Understanding the adoption of green practices in large firms, particularly in comparison to manufacturing SMEs, could highlight distinct organisational behaviours, resource allocation strategies, and the impact of size on green innovation adoption. Comparative studies could offer valuable insights into how larger firms can collaborate with manufacturing SMEs to foster innovation in the green sector.

Furthermore, the study faced constraints regarding its sample size and geographical scope. The data was collected from manufacturing SMEs located

in the top five states/federal territory of Malaysia, including Selangor, Johor, Kuala Lumpur, Perak, and Penang, rather than encompassing a nationwide representation. This limited scope might affect the generalisability of the findings to other regions or contexts. Future studies should aim for a broader geographical scope, ideally with a nationwide sample. By including manufacturing SMEs from different regions of Malaysia, researchers can capture a more representative view of green innovation adoption across the country, taking into account regional variations in market dynamics, regulatory environments, and access to green technologies.

In addition, given the limited mediating effects observed, future research should investigate alternative organisational mechanisms that might better explain the indirect pathways linking external drivers and green innovation adoption. Potential mediators include green human resource management, sustainability-oriented organisational learning, environmental knowledge sharing, and green transformational leadership. These constructs may provide richer insights into how internal behavioural and managerial processes contribute to green adoption in the Malaysian SME context.

Lastly, the study was conducted within the context of a developing country, Malaysia. The results and insights might vary if the research were replicated in developed countries, where the market environment, institutional frameworks, and green innovation capabilities may differ significantly. It is recommended that future research should explore green innovation adoption in developed countries within the Asia Pacific, Europe, or United States. Cross-

country comparisons could help identify differences in institutional frameworks, market pressures, and technological capabilities, offering a broader perspective on green innovation adoption in various economic contexts.

## 5.8 Conclusion

This research highlights the impacts of institutional environment, market environment, and internal organisational factors on manufacturing SMEs' access to green innovation adoption. The findings acknowledged that eight out of 14 hypotheses were supported whereas six were not supported. Despite its limitations, this study sets the stage for future research to explore the longitudinal impact of these factors, the role of emerging technologies, and the broader contextual variables influencing green innovation adoption. Ultimately, fostering an interaction between organisational culture, technology, and institutional support is essential for driving green innovation and achieving long-term sustainability.

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**APPENDIX**

**UNIVERSITI TUNKU ABDUL RAHMAN**

**Faculty of Business and Finance**
**MASTER OF PHILOSOPHY**

**Title of topic: Green Innovation: The Role of Green Dynamic Capability, Organisational Green Culture, & Big Data Analytics in Manufacturing SMEs**

**Survey Questionnaire**

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Dear Sir/Madam:

My name is Muhammad Hamza, currently pursuing Master of Philosophy (MPhil) at Universiti Tunku Abdul Rahman (UTAR). I am conducting research entitled "**Green Innovation: The Role of Green Dynamic Capability, Organisational Green Culture, & Big Data Analytics in Manufacturing SMEs**" to meet the award requirements for MPhil.

All information collected from this survey will remain strictly confidential. Your participation in this survey will be appreciated. If you require any clarification or have any comments or suggestions on the study, please do not hesitate to contact me by email at Muhammad.hamza65677@gmail.com (+60 11-2073 0506)

Thank you for your time and co-operation.

By submitting or providing your personal data in this study, it is deemed that you have consentedand agreed for your personal data to be used in this study. Your data will be processed and protected in accordance with the provision of the Personal Data Protection Act 2010.

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I understand that my participation is voluntary, and I am free at any time to withdraw from the study without giving any reasons. I understand that the information obtained from this study will help in achieving the objectives of this study. I give my consent to participate in this survey.

Yes □ No □

**DISCLAIMER:** The following questions are for analytical purposes only and all answers and information in this section will be kept confidential. It will not be used to specifically identify any individual.

**Questionnaire**

**Section A: Firm & Personal Information**

1. Your gender:
    - Male
    - Female

2. Your age group:
    - Below 20 years
    - 20 – 29 years
    - 30 – 39 years
    - 40 – 49 years
    - Above 50 years

3. Your highest level of education:
    - No formal education
    - Primary school
    - High school
    - Certificate holders & Diploma
    - Bachelor's degree
    - Master & PhD
    - Others, please specify: _____

4. State/Federal territory in which your business is located:
    - Selangor
    - Penang
    - Johor
    - Kuala Lumpur
    - Perak
    - Others, please specify: _____

5. Your job position in the firm:
    - Owner/Company Founder
    - CEO/CFO/Director
    - Manager/Assistant Manager
    - Others, please specify: _____

6. Your manufacturing industry:
    - Paper and Allied Products
    - Chemicals and Allied Products
    - Primary Metal Industries
    - Machinery and Computer Equipment
    - Electrical and Electronic Equipment
    - Transportation Equipment
    - Food and Beverages Industries
    - Miscellaneous Manufacturing Industries (Medical Equipment and Supplies, Jewellery, Sporting Goods, Toys, and Office Supplies, etc)

- Others, please specify: _____

7. What is the number of full-time employees in the organisation?
    - Less than 5
    - 5 - 75
    - 76 - 200
    - More than 200

8. What is the estimated revenue per year for your business?
    - Less than RM300,000
    - RM300,000 to less than RM15,000,000
    - RM15,000,000 to less than RM50,000,000
    - More than RM50,000,000

**Section B**

Please stipulate the degree to which you agree with the following statements in regard to your firm on a scale from 1 to 7, where 1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Strongly Agree.

**Part 1a: Formal institutions and manufacturing SMEs access to green innovation**

This part establishes how formal institutions are related to manufacturing SMEs access to Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My manufacturing organisation faces various environmental regulations that urge us to adopt pollution control in production processes. | | | | | | | |
| 2 | My manufacturing organisation faces a set of environmental regulations that present standards that must be obeyed. | | | | | | | |
| 3 | My manufacturing organisation faces a set of environmental regulations that stipulate the need to pay pollution fines for exceeding pollution limits. | | | | | | | |
| 4 | My manufacturing organisation faces environmental regulations in various manufacturing processes. | | | | | | | |

**Part 1b: Informal institutions and manufacturing SMEs access to green innovation**

This part establishes how informal institutions are related to manufacturing SMEs to adopt Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | Business partners put pressure on my organisation to adopt environmentally friendly activities in order to reduce environmental effects. | | | | | | | |
| 2 | Competitors' practices put pressure on my organisation to adopt environmentally friendly strategies. | | | | | | | |
| 3 | Societal norms and culture put pressure on my organisation to engage in environmentally friendly procedures. | | | | | | | |
| 4 | The public, including third-party environmental organisations and social media, put pressure on my organisation to adopt environmentally beneficial activities. | | | | | | | |

**Part 2a: Customers green demand and manufacturing SMEs access to green innovation**

This part establishes how customers green demand are related to manufacturing SMEs access to Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My organisation’s loyal consumers are profoundly concerned about the environment. | | | | | | | |
| 2 | My organisation’s loyal customers demand environmentally friendly products. | | | | | | | |
| 3 | My organisation gets motivated to improve our dedication to sustainability due to the Customer's green demands. | | | | | | | |
| 4 | My organisation’s loyal consumers often address environmental concerns. | | | | | | | |

**Part 2b: Green competition and manufacturing SMEs access to green innovation**

This part establishes how green competition is related to manufacturing SMEs to adopt Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My organisation develops a green image compared to competitors via environmental standards. | | | | | | | |
| 2 | My organisation's main competitors establish environmental guidelines for their business activities. | | | | | | | |
| 3 | My organisation can enhance market share through the implementation of environmental standards. | | | | | | | |
| 4 | My organisation can gain a competitive edge by adopting environmental friendly strategies. | | | | | | | |

**Part 3: Green dynamic capabilities and manufacturing SMEs access to green innovation**

This part establishes how green dynamic capabilities are related to manufacturing SMEs to adopt Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My organisation can improve work efficiency by integrating internal and external resources. | | | | | | | |
| 2 | My organisation has the ability to monitor the environment in order to identify environmental friendly possibilities. | | | | | | | |
| 3 | My organisation can absorb, learn, integrate, share, and apply new green knowledge. | | | | | | | |
| 4 | My organisation is able to successfully allocate resources to develop green innovations. | | | | | | | |
| 5 | My organisation has the capability of successfully integrating specialised green knowledge within the organisation. | | | | | | | |

**Part 4: Organisational green culture and manufacturing SMEs access to green innovation**

This part establishes how organisational green culture is related to manufacturing SMEs to adopt Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My organisation makes an effort to ensure that every employee understands the importance of environmental preservation. | | | | | | | |
| 2 | My organisation aims to make environmental protection a priority in all departments. | | | | | | | |
| 3 | My organisation has a clear policy statement encouraging sustainability in every business operation aspect. | | | | | | | |
| 4 | Environmental preservation is a high-priority activity in my organisation. | | | | | | | |
| 5 | My organisation places a central corporate value on environmental preservation. | | | | | | | |

**Part 5: Big data analytics capability and manufacturing SMEs access to green innovation**

This part establishes how big data analytics capabilities are related to manufacturing SMEs access to Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My organisation possesses advanced technologies for data analysis. | | | | | | | |
| 2 | My organisation gathers data from various sources and uses it for analysis on advanced tools. | | | | | | | |
| 3 | My organisation applies data visualisation strategies to aid decision-makers in comprehending complex information gathered from vast quantities of data. | | | | | | | |
| 4 | My organisation's dashboards offer information that is useful for necessary diagnostics. | | | | | | | |
| 5 | My organisation has connected dashboard information with the manager’s communication devices. | | | | | | | |

**Part 6: Manufacturing SMEs access to green innovation**

This part establishes how manufacturing SMEs access to Green Innovation in Malaysia.

| | Attributes | Rating | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | My organisation selects ingredients for products that minimise environmental risks. | | | | | | | |
| 2 | My organisation optimises energy consumption during the manufacturing process. | | | | | | | |
| 3 | My organisation ensures that the product becomes recyclable and reusable. | | | | | | | |
| 4 | My organisation selects a manufacturing process that generates minimal waste and produces the minimum environmental pollution. | | | | | | | |
| 5 | My organisation recycles and reuse waste material generated throughout the manufacturing process. | | | | | | | |

End of the questionnaire.

Thank you.

**Adjusted Sample Size Calculation for Top 5 States**

| States/Federal Territory | Population by States/Territory (%) | Formula | Sample size |
|---|---|---|---|
| Selangor | 20.0% | (20.0 / 64.8) × 204 = 62.96 | 63 |
| Johor | 16.4% | (16.4 / 64.8) × 204 = 51.64 | 52 |
| Kuala Lumpur | 10.9% | (10.9 / 64.8) × 204 = 34.29 | 34 |
| Perak | 9.0% | (9.0 / 64.8) × 204 = 28.33 | 28 |
| Penang | 8.5% | (8.5 / 64.8) × 204 = 26.78 | 27 |
| **Total** | **64.8%** | | **204** |

## Literature Gap

| | Author(s), Year | Independent Variable | Dependent Variable | Mediating Variable | Moderating Variable | Methodology | Respondents | Key Findings |
|---|---|---|---|---|---|---|---|---|
| 1 | Yu et al., 2022 | GDC | GIA | Nil | BDAC, Environmental Dynamism | Comparative Quantitative Analysis | 220 SMEs (from Pakistan and Malaysia) | The result shows GDC positively affects GIA, but environmental dynamism does not moderates between GDC and GIA. Moreover, BDAC positively moderates between GDC and GIA. |
| 2 | Zhang, Liang, et al., 2020 | Environmental regulation | Green Innovation | external knowledge adoption | green absorptive capacity | Quantitative Analysis | 237 manufacturing firms in China | H1 argued for positive effects of environmental regulations on external knowledge adoption. H2 and H3 predicted that external knowledge adoption mediates the effects of environmental regulations on green innovation. H4 was posited that green absorptive capacity strengthens the relationship between environmental regulations and external knowledge adoption. |

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|---|---|---|---|---|---|---|---|---|
| 3 | da Silva et al., 2023 | Technological Factors, Organisational Factors, Environmental Factors | Green Innovation Adoption | Nil | Nil | Qualitative Analysis | 13 Firms ABAM (Brazilian Association of Starch and Cassava Producers) and SIMP (Union of Cassava Producers in Paraná) | The findings suggest that behavioural factors for GIA, such as collaborative behaviours, productivity, safety behaviours, and green behaviours, are directly associated with other determining factors, such as knowledge, operating costs, stakeholder pressure, economic benefits, information access, customer assessment, organisational compatibility, and business support. Furthermore, GIA can lead to the effective implementation of sustainable practices to enhance economic performance and effective environmental management. |
| 4 | Bakarim et al., 2024 | Nil | Green Innovation | Nil | Nil | Systematic Literature Review | 24 studies | Based on the findings of the investigations, five variables (green product innovation, green process innovation, green services innovation, green managerial innovation and green marketing innovation) have been highlighted as elements of Green Innovation for organisations. |

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|---|---|---|---|---|---|---|---|---|
| 5 | Z. Chen & Liang, 2023 | Institutional Environment (Formal, Informal), Market Environment (CGD, GC) | GI Practices | Top Management Environmental Awareness | Big Data Analytics Capability | Quantitative Analysis | 209 enterprises located in China | The results indicate that GC is the strongest driver of GI, followed by FI, II, and CGD. Top management awareness mediates the effect of these external factors and GI, with distinct effects observed for different types of awareness. Additionally, BDAC moderates the relation between external drivers and environment awareness of the top management. |
| 6 | Jassim & Challoob, 2021 | Green Innovation | Environmental Sustainability | Nil | Nil | Quantitative Analysis | 275 employees of Al Zawraa General Company | The research reached a set of conclusions, the most important of which is that green innovation has a moral impact on environmental sustainability. |
| 7 | Jayaraman et al., 2023 | Customers, Government Regulation, Suppliers, Employees | Sustainability Performance (Social Performance, Environmental Performance, Economic Performance) | Green Innovation | Nil | Quantitative Analysis | Federation of Malaysian Manufacturers (FMM) and SME Corporation Malaysia (Kuala Lumpur, Malaysia) | The findings from this conceptual paper suggest that internal and external stakeholders (customers, government regulation, suppliers, and employees) have a significant effect on organisational sustainability performance, especially with green innovation initiatives. Stakeholders |

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| 8 | Khan et al., 2022 | Green Innovation Practices | Consumer Resistance to Green Innovation Products | Nil | Environment Knowledge, Pro-environmental Behaviour | Quantitative Analysis | 750 SME employees (Johar, Penang, and Selangor) | A cross-sectional online survey of 750 SME employees revealed numerous significant causal associations between green innovation practices and consumer resistance to green product innovation. Additionally, the moderating effect of environmental awareness and pro-environmental behaviour was assessed. The results supported the predicted moderating relationships. |
| 9 | H. Li, 2022 | Green Innovation | Firm Performance (Market Performance, Financial Performance), Green Dynamic Capability (Green Resource Integration Capability, Organisational Learning Capability, Environmental Insight Capability) | Green Dynamic Capability (Green Resource Integration Capability, Organisational Learning Capability, Environmental Insight Capability) | Nil | Quantitative Analysis | 236 heavy-polluting manufacturing firms in China | The results show that GI is positively correlated with both enterprise performance and GDC, whereas GDC also has a significant impact on enterprise performance. |

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|---|---|---|---|---|---|---|---|---|
| 10 | H. Wang et al., 2021 | Stakeholders View (Competitor Pressure, Governmental Pressure, Employee Conduct), Green Innovation Practices | Green Innovation Practices, Organisations Performance Environmental Performance | Nil | Innovation Orientation | Quantitative Analysis | 515 manufacturing and services firms of Punjab province in Pakistan | Our findings proved a positive and significant link between stakeholders' views on GI practices. A significant association has been found between Green Innovation practices and environmental and Organisational Performance. The moderating effect was found to be negative but statistically significant. |
| 11 | S. Wang et al., 2022 | Green Knowledge Management, Green Innovation | Green Innovation, Corporate Sustainable Development | Nil | Green Innovation, Organisational Green Culture | Quantitative Analysis | 351 services and manufacturing firms in Turkey | Green Knowledge Management strengthens organisational capabilities to achieve green innovation and SDG as per the findings. Moreover, green innovation has also been found to be a significant positive predictor of corporate sustainable development. It is also found that Organisational Green Culture strengthens the relationship between Green Knowledge Management and green innovation for achieving SDG. |

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|---|---|---|---|---|---|---|---|---|
| 12 | Thomas et al., 2021 | Customers, Suppliers, Financiers/Investors, Employees, Public Administrations, Universities, Research Centres and Other Agencies, Community, Competitors | Green Innovation Adoption | Nil | Nil | Quantitative Analysis | 222 innovative Italian SMEs | The authors found that the stakeholders with not-contractual ties with SMEs affect green innovation. Among stakeholders with not-contractual ties only workforce represents a strong stimulus to eco-innovate. Anyway, contrary to expectations, public administrations exert a negative influence; that is, they appear to hinder SMEs approach approach towards green innovation. |
| 13 | Sukri et al., 2023 | Eco-Innovation Capabilities | Business Performance | Nil | Nil | Qualitative Analysis | 6 top-level managers/owners of Malaysian manufacturing SMEs | According to the findings, eco-innovation capabilities encourage SMEs to engage in waste management, recycling or reusing resources, research and development, sustainable goods that utilise customer requests, and the use of environment management machines. |

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| 14 | C. H. Wang, 2020 | Green Market Orientation (Green Customer Orientation, Green Interfunctional Orientation, Green Competitor Orientation) | Green Performance, Green Innovation | Green Innovation | Nil | Quantitative Analysis | 248 high-tech firms in Taiwan | The results highlight three subconstructs of green market orientation in facilitating green innovation and green performance. Green innovation fully mediates the association between green interfunctional orientation and green performance. However, green innovation only partially mediates the effects of green customer orientation and green competitor orientation on green performance. |
| 15 | Waqas et al., 2021 | BDA Talent Capability, Business Analytics, BDA Capability Management | Green Innovation, Green HRM Practices | Green Innovation, Green HRM Practices | Organisational Commitment, Corporate Green Image | Quantitative Analysis | 294 responses from manufacturing firms in China mainland | Big Data Analytics improves competitive advantage and environmental performance. Green Innovation and Green HRM enhance competitive advantage via corporate green image. Green Innovation, Green HRM, and competitive advantage act as mediators, while organisational commitment and corporate green image serve as moderators in the Chinese manufacturing context. |

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| 16 | Al-Khatib, 2022 | Big Data Analytics Capabilites, Green Radical and Green Incremental Innovation | Competitive Advantage, Green Radical and Green Incremental Innovation | Green Radical and Green Incremental Innovation | Data-driven Culture | Quantitative Analysis | 356 industrial firms in Jordan | The empirical results validated the proposed moderated-mediation model, with statistically significant relationships among the constructs. Big Data Analytics Capabilities positively influenced competitive advantage, mediated by both green radical and green incremental innovation. Additionally, a data-driven culture moderated the relationships between these green innovation types and competitive advantage. |
| 17 | Sun et al., 2024 | Interactive Information Provision, Online Participation Creation, User Independent Innovation | Green Innovation | Green Dynamic Capability | Social Media Use | Quantitative Analysis | 338 Chinese manufacturing enterprises industry in five province (Beijing, Shandong, Jiangsu, Shaanxi, and Henan) | Among the three forms of customer participation, interactive information provision and online participation creation have a positive impact on enterprise green innovation. Compared with interactive information provision, the impact of online participation creation on green innovation is stronger, while user independent innovation has no significant impact on green innovation. In |

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| | | | | | | | | addition, in terms of mediating effect, green dynamic capability had a partial mediating role in the relationship between customer interactive information provision and green innovation and online participation creation and green innovation. In terms of the moder- ating effect, enterprise social media use had a positive moderating role in the relationship between interactive information provision and green dynamic capability and online participation creation and green dynamic capability. |
| 18 | Yuan & Cao, 2022 | Corporate Social Responsibility, Green Dynamic Capabilities | Green Innovation (GPI, GPI), Green Dynamic Capabilities | Green Dynamic Capabilities | Nil | Quantitative Analysis | 424 manufacturing companies in China | We find that: (1) CSR practice significantly promotes GI. (2) GDC significantly promotes GI. (3) GDC functions as a mediator between CSR and GI. |

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|---|---|---|---|---|---|---|---|---|
| 19 | Ali et al., 2021 | Green Human Capital, Green Structural Capital, Green Relational Capital | Green Innovation Adoption | Nil | Nil | Quantitative Analysis | 235 SMEs from the four manufacturing sectors of Pakistan (textile, chemical, pharmaceutical, and steel) | The empirical results of this research indicate that green human capital and green structural capital significantly increase green innovation adoption. However, it must be noted that green relational capital has a positive but insignificant impact on green innovation adoption in manufacturing SMEs in Pakistan. |
| 20 | Z. Huang & Xiao, 2023 | Dynamic Capabilities (Absorptive Capability, Reconfiguring Capability), Environmental Management Capabilities | Eco-innovation (Eco-process Innovation, Eco-product Innovation) | Environmental Management Capabilities | Stakeholder Pressure | Quantitative Analysis | 169 Chinese manufacturing firms | The results show that environmental management system (EMS) completely mediates the relationship between dynamic capabilities (including absorptive capability and reconfiguring capability) and eco-innovation (including eco-process and eco-product innovation). Furthermore, the relationship between absorptive/reconfiguring capabilities and EMS, as well as the direct and indirect relationship between absorptive capability and eco-process innovation, is contingent upon |

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| | | | | | | | | stakeholder pressure. The direct and indirect effects become stronger when managers perceive higher stakeholder pressure. |
| 21 | X. Lin & Su, 2024 | Coercive Environmental Regulatory Pressure, Incentivised Environmental Regulatory Pressure, Market Competition Pressure, Social Norms Pressure, Green Dynamic Capability | Green Product Innovation, Green Process Innovation, GDC | Green Dynamic Capability | Executive Environmental Attention | Quantitative Analysis | 357 Chinese middle-senior managers or above in manufacturing companies | External green pressures mostly have a significant impact on green innovation, the green dynamic capability as a mediator. Also, executive environmental attention moderates a connection between external green pressure and GDC. |
| 22 | Dong et al., 2024 | Institutional Benefits (Government Support, Social Legitimacy), Corporate Green Innovation | Corporate Green Innovation, Competitive Advantage | Corporate Green Innovation | Big Data and Predictive Analytics | Quantitative Analysis | 226 Chinese manufacturing firm | The empirical findings show both formal (e.g. government support) and informal (e.g. social legitimacy) institutions positively influenced corporate competitive advantage. Green innovation acted as a mediator in the relationship between external institutions and competitive advantage. The adoption of big data and predictive analytics positively moderated this mediation effect. |

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|---|---|---|---|---|---|---|---|---|
| 23 | Lestari & Sunyoto, 2023 | Environmental Regulation, Customer Pressure, Management Commitment, Resources and Capabilities, Green Innovation | Green Innovation, Sustainable Performance | Nil | Nil | Quantitative Analysis | 160 food sector SMEs in Malang Raya, Indonesia | The empirical results conclude the positive effects of customer pressure, resources and capabilities, and commitment management on green innovation, which in turn had a positive on sus- tainable performance. The results also confirmed that envi- ronmental regulations did not significantly impact green innovation. |
| 24 | Alkhatib, 2024 | Big Data Analytics Capabilites, Green Supplier Integration, Green Customer Integration, Green Internal Integration | Green Innovation, Green Supplier Integration, Green Customer Integration, Green Internal Integration | Green Supplier Integration, Green Customer Integration, Green Internal Integration | Nil | Quantitative Analysis | 300 respondents from food and beverages manufacturing firms located in Jordan | The results revealed that big data analytics capabilities positively and significantly affects both green supply chain integration and green innovation. In addition, the results demonstrated that green supply chain integration positively and significantly affects green innovation. Further, it is also found that green supply chain integration positively and significantly mediates the relationship between big data analytics capabilities and green innovation. |

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| 25 | Yousaf, 2021 | Green Practices, Green Dynamic Capability | Green Innovation, Green Value Co-creation | Green Value Co-creation | Nil | Quantitative Analysis | 370 SMEs from 8 big cities of Pakistan | Empirical results proved that green dynamic capabilities, green practices, and green value co-creation improve the mechanism of green innovation in SMEs. |
| 26 | Imran et al., 2021 | Green Organisational Culture, Green Innovation, Environmental Performance | Organisational Performance, Green Innovation, Environmental Performance | Green Innovation, Environmental Performance | Nil | Quantitative Analysis | 170 responses from Malaysia's industrial and service organisations (Malacca, Johor, Selangor, and Kedah) | Green organisational culture was a significant predictor of green performance in this research. Furthermore, the find- ings reveal that environmental performance and green innovation fully mediate the relationship between green organisational culture and organisational performance. |
| 27 | C.-H. Wang, 2019 | Organisational Green Culture | Green Performance, Competitive Advantage, Green Innovation | Green Innovation | Nil | Quantitative Analysis | 327 manufacturing firms of different industry sectors in Taiwan | The findings of this paper suggest that OGC significantly predicted green performance and competitive advantage, respectively. Moreover, the results show that both green innovation completely mediates between OGC and green performance, and that it has a partially mediating effect on the relationship between organisation green culture and competitive |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | | advantage under environmental pressure. |
| 28 | S. K. Singh et al., 2022 | Stakeholder Pressure, Green Dynamic Capabilities, Green Innovation | Green Dynamic Capabilities, Green Innovation, Firm Performance | Green Dynamic Capabilities, Green Innovation | Nil | Quantitative Analysis | 248 manufacturing SMEs in Abu Dhabi, UAE | The study results indicate that stakeholder pressure influences green dynamic capability, green dynamic capability influences green innovation, and green innovation influences firm performance. Furthermore, results also suggest that green dynamic capability mediates the influence of stakeholder pressure on green innova- tion and green innovation mediates the impact of green dynamic capability on firm performance. |
| 29 | Roespinoedji et al., 2019 | Green Organisational Culture, Green Product Innovation, Green Process Innovation, Competitive Advantage | Green Product Innovation, Green Process Innovation, Competitive Advantage, Envrionmental Performance | Nil | Nil | Quantitative Analysis | 350 manufacturing organisations in Malaysia | The results of the examination confirm that green product innovation, green process innovation and competitive advantage have positive and significant influenced by green organisational culture. Moreover, the results of PLS-SEM likewise confirm that competitive advantage is positive and significantly |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | | influenced by green product innovation and green process innovation. The outcomes further affirm that competitive advantage has positively and significantly impact on environmental performance in Malaysian manufacturing firms. |
| 30 | Fang et al., 2022 | Green HRM, Green Innovation, Green Culture | Environmental Performance, Green Innovation, Green Culture | Green Innovation, Green Culture | Nil | Quantitative Analysis | 290 employees from Manufacturing firms in Malaysia (Penang, Johor, and Selangor) | The research results provide managers with a better knowledge of how GHRM helps develop sustainable culture and green innovation and how these elements contribute to the improvement of environ- mental performance inside the organisation. This study also makes a significant contribution in terms of novelty and research relevance by demonstrating that green culture and green innovation positively mediate the relationship between GHRM and environmental perfor- mance in a sustainable manner. Managers will understand the GHRM required to develop an ecologically |

conscious culture and promote green innovation among environmentally conscious employees.