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Investigating the Potential for Transformation of Korean Manufacturing SME Using Digitalization: Focusing on Data Ecosystem Strategies of Germany and Japan

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Abstract The study provides suggestions on key technologies for the fourth industrial revolution to the Korean government and business community. It also lays foundation for the creation of strategies and policy adjustments for the design and development of innovative ecosystems. Therefore, the study's purpose is to evaluate the potential for DX to transform Korean SMEs from the perspective of Japanese and German data ecosystems. With a focus on their industrial and technological developments, the study chooses model nations that are geopolitically comparable to Korea. Findings of the study show that a majority of Korean manufacturing SMEs are unaware of the importance of DX. Korean SMEs seem to have varying degrees of preparedness and goals when it came to pursuing DX, such as process improvement, product innovation, and manufacturing innovation. By carefully applying DX at the most beneficial places in the value chains of their respective industries, businesses may optimise their profits. Therefore, Korean policymakers should enact measures that facilitate technological innovation and offer appropriate settings and infrastructure for enterprises to integrate DX-related technologies.

Keywords Digital transformation, Manufacturing SMEs, Data ecosystem, Digitalization

1. Introduction

1.1. Background

The digital transformation of Korea underscores the necessity of enacting laws that support technological progress and motivate companies to embrace digital transformation (Chung et al., 2022). For small and medium enterprises (SMEs) to have access to digital platforms and technology, infrastructure development is essential (Brodeur et al., 2021). Policies that support digital transformation (DX) should consider the industry's current features, challenges, and shifting trends (Autio and Thomas, 2020; Lingens, et al., 2021). The four industries examined — IT services, non-IT services, IT manufacturing, and non-IT manufacturing — showcase different levels of progress in the area of DX. These differences should be considered by businesses and legislators when creating their DX strategies (Kagermann et al., 2012; Spath et al., 2021).

Several business goals are met by DX, including increased productivity, improved cost-effectiveness, improved competitiveness, support for R&D for new goods and services, and differentiation and innovation of current offerings (Kagermann et al., 2012; Spath et al., 2021). The fact that the DX phenomenon is largely spontaneous can be attributed to the extensive usage of artificial intelligence (AI), smart manufacturing, online services, digital platforms, metaverse systems, and online services. Korea does not have enough strategy or understanding of the digital transformation (Chung et al., 2022). The nation's present digital transformation projects are still in their early stages. The expected benefits of DX have not yet been completely appreciated by organisations. Korean businesses are less capable of DX than their international competitors.

Korea has been advocating for the incorporation of fundamental technologies associated with the Fourth Industrial Revolution into their enterprises. In order to adjust to the changing global supply chain structures, DX is crucial (Association, 2022). Businesses must adopt new technologies in the fourth industrial revolution to foster innovation and digital transformation (Denyer and Tranfield, 2009). Developed countries have put legislation into place to guarantee truthful business representation and to promote the deployment of appropriate technologies. The Korean government emphasises how big data, artificial intelligence, and smart factories can boost the country's industrial sector's competitiveness (Chung et al., 2022). In order to prepare for the fourth industrial revolution, the Korean government prioritises innovation, convergence, and integration in

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fundamental technologies. The technology of the fourth industrial revolution is drawing interest because of its predicted effects on the post-COVID-19 global supply chain structure (Abudaqa et al., 2022).

1.2. Research Rationale and Purpose

Technologically sophisticated nations such as Korea have pushed their industries to use the key technologies of the Fourth Industrial Revolution in recent years. This is done in an effort to address the shifting global supply chain architecture in an efficient manner (Cannas, 2021). Businesses must embrace new technology as a crucial component of the digital transformation process for innovation in the fourth industrial revolution era (Chung et al., 2022). The majority of industrialised countries have passed legislation to encourage the use of suitable technology and appropriately represent the nature of their industries (Abudaqa et al., 2022; Albinson et al., 2016; Candelo et al., 2021). The Korean government highlights how the country's manufacturing sector is now more competitive as a result of the use of big data, artificial intelligence, and smart factories (Chung et al., 2022). When it comes to the fundamental technologies of the fourth industrial revolution, the Korean government places a high priority on innovation, convergence, and integration. The fourth industrial revolution's technology is drawing more attention as it is expected to be essential in altering the structure of the world's supply chains following the COVID-19 pandemic (Abudaqa et al., 2022).

The purpose of this study is to evaluate the effects of DX on Korean SMEs from the perspective of Japanese and German data ecosystems. The aim of this study is to suggest key technologies for the fourth industrial revolution to the Korean government and business community. It also seeks to direct the creation of strategies and policy adjustments depending on the results of the study. It argues that the Korean government should be aware of the convergence and integration traits of smart technology. When the technology support policy for SMEs integrates these technological characteristics, performance will improve. This study is significant because it validates the relationship that Appio et al.'s research found between supply innovation and the adoption of new technology.

Hence, Germany and Japan, two nations that are actively attempting to create a data ecosystem, were selected for review for this study. In the age of data competitiveness driven by the US and China, it evaluates their approaches to smart manufacturing and provides three recommendations for Korean SMEs looking to create a data platform ecosystem (Chung et al., 2022). With a focus on their industrial and technological developments, the study chooses model nations that are geopolitically comparable to Korea (BMWi, 2020). As a result, the digital initiatives of Japan and Germany are highlighted as case studies. The policies and tactics pertaining to innovation in smart manufacturing are then covered in this research. The research, then, looks critically at how Korea is affected by the data ecosystem strategies of these nations.

2. German and Japanese Data Ecosystem Strategies

The governments of major economies, like the US, Germany, China, and Japan, have put laws into place to encourage the digital transformation of their nations' enterprises and industries. In an effort to adapt to the digital revolution, multinational firms are actively forging new alliances and completing mergers and acquisitions (M&A) (vom Brocke et al., 2009). In line with the present trend, the Korean government unveiled the Strategy for the Innovative Growth of Digital Industries in August 2020 and the Korean New Deal Programme 2.0 in July 2021 (Chung, 2021). The DX policy is officially supported by the Industrial Digital Transformation Promotion Act (IDTPA), which was passed by the Korean government in December 2021. Korea's DX technology capability is still less advanced than peer countries (Han, 2020). To expedite the development of human capital and simplify rules, more reforms are required.

2.1. Germany’s Industry 4.0 Strategy

Germany, a significant industrial power, has acknowledged that it faces difficulties competing with nations like China and Southeast Asia due to its comparatively high wage costs (BMWi, 2020). The Industry 4.0 strategy in Germany considers both the supply-side and market-side viewpoints. Integrating value creation networks with the production process is the goal for businesses (Autio and Thomas, 2020; Lingens, et al., 2021; OECD, 2022). All links in the value chain, including front-end services and back-end product design and development, must be integrated in order to do this. Due to their dominance in the global manufacturing industry and integration of information and communication technology (ICT) into their production processes, German companies have emerged as pioneers in the field of intelligent manufacturing technologies (Seidel, 2021). Germany views developments in smart manufacturing as extending beyond business-related technological advancements (Germany, Trade and Invest, 2014). According to BMWi (2020), it is a shift in society meant to guarantee that the advantages of technological progress are distributed fairly. Germany views innovation in smart manufacturing as encompassing more than just process automation. They see it as a means of rearranging the whole value chain of the product (Association G-X, 2022).

Government support for research and development, along with university and private company partnership to develop these technologies, are key components of Germany's Industry 4.0 setup. In recent times, the development of successful and efficient systems has been made possible by technologies such as artificial intelligence, cyberphysical systems, and the Internet of Things (IoT). Businesses in nations with less developed technology infrastructure can build and use these systems if they have the financial means to do so. For example, General Electric's "Industrial Internet," IBM's "Industry 4.0," Cisco's "Internet of Everything," and Hitachi's Lumada are just a few of the services that the country and businesses

depend on (Association, 2022; Birkel & Wehrle, 2022). A precedent was created on December 9, 2020, when Turkey and the World Economic Forum (WEF) worked together to open the fourth Industrial Revolution Centre in Turkey. Turkey is one of many countries that organises, plans, and budgets for the adoption of Industry 4.0 and new industrial technologies.

Industry 4.0 is becoming more and more attractive to companies in the industrial sector as a competitive advantage. The corporate community has taken notice of the smart factory paradigm, which has also sparked study (Kagermann et al., 2012). Many organisations have achieved significant progress in digitalization over the last ten years by taking advantage of Germany's leadership position in the sector, large client base, experience with tailored solutions, and small- and medium-sized business resilience (Salvador et al., 2020; Kagermann and Wahlster, 2022; vom Brocke et al., 2009). However, there are internal and external barriers in the sector that prevent Industrie 4.0 from being adopted. The current adoption of Industrie 4.0 by German industrial enterprises is distorted by these barriers.

When it comes to adopting digital transformation, large-scale companies and (SMEs diverge greatly, with SMEs falling behind. According to a recent study, despite pressure from competitors, some SMEs with strong financial stability are not inclined to begin digitalizing their operations. This leads to a contradiction in which success and laziness are related (et al., 2012; vom Brocke et al., 2009). Their lack of organisational culture and strategic competence prevents them from advancing the digitalization of critical tasks. Smaller companies are under more financial strain (Brodeur et al., 2021). When SMEs experience financial challenges, they usually prioritise giving up on digital projects. Instead of bolstering the essential industrial infrastructure, these projects frequently concentrate on short-term objectives inside the production chain and do not immediately produce value (Denyer and Tranfield, 2009; Klopper et al., 2007).

Compared to large-scale firms, SMEs lack good data management—a critical skill for the impending Industrie 4.0 era. AI solutions are mainly used by SMEs to improve their goods and services; internal operations are not given as much attention (Bui, 2021). An insufficient internal operations database and a lack of expertise are the outcomes of poor data management. In contrast to large-scale companies, SMEs are implementing Industrie 4.0 more slowly as the sector moves into its second decade.

Large businesses typically have more developed digitization initiatives. Certain companies are still in the process of going digital. According to Kagermann and Wahlster (2022), senior management's lack of enthusiasm for spearheading the change is frequently the cause of this. Though they are exceptions, these companies are endangering their ability to compete (Brodeur et al., 2021). Additional obstacles that large firms face during the digitalization process include privacy and data security concerns, regulatory restrictions, and uncertainty about the growth of digital initiatives (Spath et al., 2021; Salvador et al., 2020; Kagermann and Wahlster, 2022).

These factors have the potential to impact both big and small businesses, and they may also be a contributing factor to overall digitization hurdles. Furthermore, they may also affect SMEs in the latter phases of the digital transformation process (Abudaqa et al., 2022). Due to structural limitations in the Northern and Eastern areas of the country as well as a lack of adequate digital infrastructure, Germany confronts considerable obstacles when launching digital projects. The nation's low IT investment to GDP ratio—which is the fourth lowest among EU members—complicates these challenges even more (Autio and Thomas, 2020; Lingens, et al., 2021; Klopper et al., 2007).

2.2. Japan’s Society 5.0 Strategy

The Japanese government released details of the Fifth Basic Plan for Science and Technology (2016-2020) in January 2016. Through the deployment of a particular cyberphysical system, the "Society 5.0" initiative aims to improve people's safety and well-being and build a sustainable society. In Society 5.0, a system of systems is defined. It comprises using the Internet to connect different systems, such energy management and highway transportation networks, in order to address local and worldwide social issues, like lowering carbon emissions (Birkel & Wehrle, 2022). Society 5.0 takes a fresh stab at addressing societal problems. A highly intelligent society that combines big data, the Internet of Things (IoT), artificial intelligence (AI), and human services to support both digital and physical infrastructures will be formed in the future when diverse elements are networked and technologies merge. The idea is to create a community free from existing constraints and limits, where people may grow ethically in a secure and natural setting (Autio and Thomas, 2020).

Society 5.0 addresses regional and worldwide social concerns, such as the reduction of carbon emissions, by utilising linked systems, such as energy management and transportation networks. The Fifth Science and Technology Basic Plan of the Japanese government suggests "Society 5.0" as the ideal future social organisation. Japan has created long-term national ambitions, such Connected Industries and Society 5.0 (Abudaqa et al., 2022; Han, 2020). Japan takes a different tack, but Germany prioritises industrial innovation by putting Industrie 4.0 into practice. Japan's all-encompassing approach considers several facets of everyday life, culture, and business to lead the country along a new route. In Japan, public-private collaboration is highly valued. This is demonstrated by the industry's involvement in the creation of smart manufacturing policies, its consideration of the opinions of private entities, and its delegation of policy implementation responsibilities to them (Abudaqa et al., 2022). The advancement of Connected Industries is being discussed with an emphasis on maximising data utilisation, developing talent, assisting small and medium-sized businesses with their R&D, and incorporating large corporations, academic institutions, and industry associations in pertinent conferences and dialogues.

Economic advancement integrates the physical and virtual

spheres to address societal concerns in contemporary society. In order to more effectively address contemporary social concerns, this societal model places focus on the relationship between the physical world and the cyberworld, as defined and developed in the Fourth Industrial Revolution (Autio and Thomas, 2020). The foundation of this new social model is a cohesive system that successfully manages social and economic issues while simultaneously attending to the needs and interests of individuals (Birkel & Wehrle, 2022). The goal of Society 5.0 is to create new frameworks for managing autonomous systems in which corporations, educational institutions, and governmental organisations collaborate to take advantage of the interconnection of today's society (Lingens, et al., 2021).

Japan's Society 5.0's IT infrastructures are built on networks, cloud computing, data centres, and big data combined with smarter municipal infrastructures, such as transportation, electricity, and water networks. The integration of infrastructure in Society 5.0 is largely dependent on high-speed internet connections and ubiquitous mobility (Kagermann et al., 2012). The development of links between users, IoT, big data, AI, and tailored services is facilitated by urban preparedness. Additionally, it promotes labor-intensive building procedures for different kinds of IT infrastructure (Abudaqa et al., 2022).

The integration of social, economic, and environmental factors into organisational structures is known as sustainable innovation. This process of conception, research and development (R&D), and ultimate commercialization of results is all included in this integration. Products, services, technology, and new business and organisational structures are among the results (Bui, 2021). Sustainability is an essential notion for the innovation processes outlined in Society 5.0 because of its importance in the economic, social, and environmental domains (Birkel & Wehrle, 2022; Cannas, 2021). In an economic setting, sustainability and profitability are related, which poses problems for firm financial stability, resource efficiency, and economic growth. The main goals of environmentalism include controlling pollution and making responsible and effective use of natural resources. In social contexts, sustainability encompasses things like equitable distribution of resources, objectivity, moral conduct, and equal access to opportunities (Brodeur et al., 2021). By creating more social cohesion and better job possibilities, this project aims to increase economic competitiveness and promote inclusive, sustainable growth.

Society 5.0's changes to the model present chances for the creation of new protocols and frameworks. Technology, the economics, geopolitics, and psychology are all affected by these advancements. Cyberspaces' integration with physical locations will have a big impact on a lot of different parts of society, such jobs, government, private life, and industrial structure (Cannas, 2021). We call this process digital transformation. Large-scale data gathering, or big data, collected by sensors in actual locations and stored in cyberspace makes it easier to integrate physical and online worlds (Birkel & Wehrle, 2022). Big data is analysed by AI algorithms, and the findings are shown to people via audiovisual devices in real-world settings.

2.3. Industry 4.0 and Society 5.0 Relationship

Businesses have benefited from Industry 4.0 in a number of ways, including lower expenses, error-free operations thanks to AI-driven gear, and quick consumer delivery of customised items. When people don't work and make money, it becomes problematic because it casts doubt on whether there will be a market for the products made in automated factories and how people will pay for them (Spath et al., 2021; WTO, 2021; OECD, 2022). Japan has embraced Society 5.0, which harmonises science, technology, innovation, and the Sustainable Development Goals of the United Nations with its top goals. This strategy seeks to deal with the current problem. According to Society 5.0, artificial intelligence can help with a number of issues, such as air pollution, unemployment, and poverty (Autio and Thomas, 2020; Lingens, et al., 2021; Kagermann et al., 2012; OECD, 2022).

The technical developments in the industry during the Industrial Revolution in 1784 had a tremendous societal influence. The Fifth Science and Technology Basic Plan, which was published on December 18, 2015, first introduces Society 5.0. By highlighting the importance of research, technology, and innovation, the Fifth research and Technology Basic Plan sought to advance Society 5.0, sometimes referred to as the super smart society (Autio and Thomas, 2020). Artificial intelligence, cyberphysical systems, big data, the internet of things, robots, augmented reality, and cloud computing are just a few of the technologies that Industry 4.0 and Society 5.0 make use of (Association, 2022). Under government oversight, planning and modelling are carried out by government agencies, universities, and the commercial sector.

Industry 4.0 concentrates on a narrower subset of the industry, whereas Society 5.0 covers the entire society, including the industry. The main objectives of Industry 4.0 in the industrial sector are cost reduction and increased production efficiency (Association, 2022). On the other hand, Society 5.0 addresses a number of social issues, including poverty, health, and access to food and water, as well as gender equalit. The Sustainable Development Goals (SDGs) 7, 8, 9, 10, 11, 12, and 13 are intimately related to Industry 4.0 (Salvador et al., 2020). These elements include policies promoting sustainable energy usage, economic expansion, innovative business strategies, productive manufacturing, secure waste disposal, and long-term use of infrastructural systems. All of the Sustainable Development Goals (SDGs) are included in Society 5.0 (Salvador et al., 2020).

Despite its contradictory nature, Japan, a wealthy and technologically advanced country, has embraced a growth plan akin to Society 5.0. In order to imderstand the dilemma, a number of nations, including France, China, South Korea, Italy, USA, and South Korea, have created their own strategies for putting Industry 4.0-like applications into practice (Salvador et al., 2020). Planned laws make Japanese companies less competitive internationally and make it harder for them to surpass competitors (Kagermann and Wahlster, 2022). In order to close the gap and guarantee long-term economic

stability, Society 5.0 is required. The institutional strategies of Panasonic, NEC, Toyota, Fujitsu, and Hitachi incorporate Society 5.0.

In Japan, the percentage of people 65 and older is now 26.7%, and by 2050, it is expected to rise to 40%. Japan has had a number of difficulties in addition to an ageing population. The Ministry of Economy, Trade, and Industry (METI) claims that old drivers are frequently at blame for deadly car crashes. It is anticipated that by 2025, the amount spent on social security for the elderly would rise from 120 trillion yen in 2015 (Salvador et al., 2020). Japan wants to use Society 5.0 to address the issues brought about by its ageing population. This involves preserving economic stability while guaranteeing the long-term delivery of social insurance programmes (Albinson et al., 2016; Anim-Yeboah et al., 2020; Cannas, 2021).

Japan's population is expected to drop from 127 million in 2030 to 117 million in 2050. Since 1980, the number of people living in Japan's cities has declined, with 503 out of 790 cities reporting a reduction in population (Birkel & Wehrle, 2022). Between 1950 and 1970, the majority of Japan's major infrastructure projects, including roads, bridges, and water lines, were built. The decay of these buildings throughout time necessitated the building of new ones (Birkel & Wehrle, 2022). An efficient method for structuring infrastructure systems is Society 5.0 (Birkel & Wehrle, 2022).

Based on statistical data, Japan ranked sixth globally in terms of greenhouse gas emissions in 2016. As mandated by the Paris Treaty, Japan seeks to reduce its greenhouse gas emissions by 26% from 2013 levels by 2030 (Birkel & Wehrle, 2022). Actions are done to guarantee a decrease in energy usage, such as promoting solar energy systems and installing energy-efficient smart lighting in houses (Abudaqa et al., 2022; Cannas, 2021). According to an examination of figures from 2016, 18% of Japan's total greenhouse gas emissions come from the country's transport industry. In order to lower greenhouse gas emissions from automobiles, the focus is on electric vehicles (BEVs), natural gas vehicles (NGVs), and hydrogen vehicles (FCVs) (Abudaqa et al., 2022; Cannas, 2021). By 2050, Toyota intends for all of its cars to be powered entirely or partially by electricity. It is anticipated that the development of smart cities and enhanced infrastructure would make address descriptions based on drivers' real-time whereabouts more effective (Abudaqa et al., 2022; Cannas, 2021). By improving the measurement of sites used, this will aid in the reduction of greenhouse gas emissions.

Japan's island nation status makes it vulnerable to a wide range of natural calamities, including hurricanes, tsunamis, and earthquakes. A nuclear disaster may be caused by an earthquake and a tsunami, as demonstrated by the Fukushima-Daichii nuclear plant accident in 2011 (Cannas, 2021). Japan works hard to create efficient control mechanisms to lessen the effects of natural catastrophes. The goal of Society 5.0 is to increase women's economic involvement and use smart food and agriculture applications for a sustainable social structure (Abudaqa et al., 2022; Candelo et al., 2021). Overall, to meet Japan's difficulties, Society 5.0 is a complete system that incorporates several systems and infrastructure.

3. Method

This study analyses secondary materials theoretically using desk research to investigate the effect of digitalization on Korean manufacturing SMEs, with focus on data ecosystem strategies of Germany and Japan. Using the desk research approach, a variety of data sources, including books, government publications, peer-reviewed journals, case studies, reports, and academic papers, were analysed and reviewed. The secondary sources were chosen based n how well they supported the objectives of the study, which included presenting a range of opinions and concepts regarding the effects of Japanese and German data ecosystem on the digitalization on Korean manufacturing SMEs.

The data ecosystems in Japan and Germany, as well as manufacturing SMEs in Korea, were the two main subjects of this investigation. These served as the research's analytical framework. Using this framework as a guide made it easier to find patterns and the best methods by going over the selected sources in a methodical way. During the analysis, the sources were reviewed to extract information and insights pertinent to the objectives of the study. The differences and similarities were carefully examined and contrasted.

4. Findings

4.1. Implications on Korean Manufacturing SMEs

Ensuring Korea’s global industrial competitiveness is essential for becoming a data-driven artificial intelligence leader, in keeping with the worldwide trend of concentrating on defining ideal business processes and creating digital platforms for fostering business innovation (Park et al., 2021). This research paper makes the case that Korean manufacturing SMEs may gain by using six characteristics taken from the Japanese and German data ecosystems.

Continuity: Germany and Japan, being leading manufacturing nations, promote smart manufacturing innovation policies with a global perspective on industrial and technical innovation strategies (Han, 2019). This indicates that their policy approach focuses on addressing social and national challenges, fostering long-term growth, and developing comprehensive national policies (Jeong, 2019). Similarly, Korea needs to expand its national smart manufacturing innovation policies to enhance the digital capabilities of SMEfrom a micro perspective.

Collaboration: Both Germany and Japan prioritise the involvement of private companies and public-private collaborations in their efforts to promote smart manufacturing innovation. Germany not only focuses on technological advancements to enhance productivity but also promotes policies that involve multiple stakeholders to prepare for changes in paradigms and societal innovation (Han, 2020).

Japan also aims to find comprehensive solutions by collaborating with both the public and private sectors (Han, 2019). In Korea, it is important to prioritise policies that foster cooperation and benefit all members of society, rather than focusing on measures that only assist specific groups of people.

Organicity: Both countries aim to implement organic measures through collaboration between local and national governments, as well as through public-private partnerships. Germany prioritises collaborations between academics and the government to develop and promote national-level innovation strategies for technological innovation (Hong et al., 2015). In 2014, the Federal Ministry of Education and Research (BMBF) no longer had exclusive authority over the national technological innovation policy called the High-Tech Strategy (Oh et al., 2021). It became a collaborative effort involving multiple ministries. Japan likewise emphasises the value of public-private collaboration and gives private groups positions that encourage them to take the initiative. Local governments are adopting this pattern from the federal government (Oh et al., 2021). It is crucial to enhance public-private cooperation and foster collaborative relationships with local governments in order to effectively develop and execute smart manufacturing innovation policies in Korea.

Network Establishment: Both nations aim to establish networks between business, academia, research institutes, and government agencies. This goal is driven by the desire to enhance overall capabilities and develop infrastructure for smart manufacturing innovation. Germany provides indirect assistance by utilising networking networks instead of offering direct aid (Oh et al., 2021). This strategy is based on the concept of reciprocal collaboration, where each policy is designed to promote common interests (Park et al., 2021). Once the Korean government achieves its current domestic policy goals, it should expand its policies to establish a network infrastructure that facilitates advanced and autonomous smart manufacturing technology. This network should be integrated into the value chain of smart manufacturing innovation, with the aim of fostering the comprehensive growth of the smart manufacturing industry in Korea.

Technological Competence: It is typical for a country to tend to protect its technological capabilities through various measures, such as enhancing industrial skills, safeguarding critical technologies, and collaborating with other institutions (Oh et al., 2021). Germany has converted regional competency centres, which previously assisted SMEs in enhancing technological innovation, into digital centres for SMEs to enhance their digital capabilities (Autio and Thomas, 2020). Japan continues to invest in five key areas to uphold its technical superiority: robots, biomaterials, smart living, plant infrastructure security, and autonomous driving and mobility services (Han, 2020). Korea needs to enhance international cooperation to secure critical technology and allocate resources promptly to establish standards for smart manufacturing.

Scalability: Germany focuses on promoting social and manufacturing innovation simultaneously to enhance quality of life and ensure social integration. An example of this can be found in the "High-Tech Strategy 2025," which includes solving social challenges as one of its three strategic aims (BMWi, 2020). The manufacturing innovation strategy aims to address the decline in labour productivity by expanding its focus to include social problem-solving and regional innovation, which leads to the creation of new value (Birkel & Wehrle, 2022). This strategy is outlined by the Ministry of Economy, Trade, and Industry (METI) in 2023. Korea must also acknowledge that social innovation may result from manufacturing innovation and put forth measures that will enable everyone in society to see the advantages of manufacturing innovation.

4.2. Korean Data Ecosystem Strategies

Through the use of smart manufacturing and smart factory applications, Korea's smart manufacturing innovation policy seeks to improve the competitiveness of manufacturing SMEs and ease their digital transition (Kim et al., 2022). A complicated geopolitical fight between the United States and China, according to some, is causing the globe to split into two spheres: one that is Sinocentric and the other that is U.S.-centric. There are rumours that Beijing may be able to dictate internet and data governance, as well as technical standards, for nations in Asia and other areas as a result of this fragmentation (Han, 2020). As the globe moves into the next stage of its digital revolution, the rivalry that was formerly thought to be purely technological and commercial has transformed into a geopolitical conflict with existential ramifications.

It's crucial to recognise, too, that China and the US are not the only significant global digital actors. Many nations, such as South Korea, Japan, and India, have been developing and exchanging legal and legislative frameworks for internet regulation in recent years. This has made the global climate for internet governance competitive. Due to its growing significance for businesses of the future and potential legal implications for the global economy, data governance is a hot issue of discussion (ABirkel & Wehrle, 2022). The national approaches to data governance in South Korea and India are different. Neither country seeks to completely embrace or support Chinese or American data practices or rules. They could also spark discussions about the rules and business plans used by the IT sector.

Korea stands out in the digital sphere since it is considered the world's most connected country. According to latest research, Korea boasts the fastest fixed broadband upload speed and the greatest worldwide availability of 4G telecoms. 96% of the nation's population, according to the Pew Research Centre, had internet connection in 2018 (Han, 2020). Korea's technical experiences have yielded vital information. Korean producers of consumer electronics, including Samsung and LG Electronics, have expanded quickly to become well-known worldwide. The influence of Korean policy and regulations on a number of industries, including manufacturing and commercial services, has been seen by the international community (Bui, 2021). Considering how interconnected Korea is, a close examination of its laws and regulations

might yield insightful information. Korean approaches have shown that persistence, a clear vision, and innovative policy frameworks may lead to a bright digital future.

4.3. Korea's Smart Manufacturing

The "Smart Factory Expansion and Diffusion Project" has been carried out by the South Korean government since 2014 in an effort to encourage the development of the manufacturing sector. The industrial sector in Korea has grown dramatically in terms of quantity. Currently, a top concern for adjusting to the changing global environment is carbon-neutral smart manufacturing (Joint Ministries, 2022). Using AI and data from advanced manufacturing, new policies seek to encourage the use of smart manufacturing in commercial settings. This strategy's main goal is to make it easier for smart factories to be established (Ministry of SMEs and Startups, 2021).

In order to efficiently and economically create customised items, a smart factory is a state-of-the-art facility that makes use of information and communication technology (ICT) to simplify all production processes, from product planning to procurement (Joint Ministries, 2022). The integration and deployment of several technologies, including cloud, AR/VR, robotics, Internet of Things (IoT), control, and robotics, has drawn a lot of attention to Industry 4.0 and smart factories. The integration and flexibility of the global value chain, as well as the application and integration of new technologies, are given priority by Industry 4.0 and smart factories. The goal of the Fourth Industrial Revolution, or Industry 4.0, is to create effective manufacturing methods that satisfy a wide range of customer needs (Joint Ministries, 2022). We call this "flexible global value chain integration." Industry 4.0 and smart factories can achieve this aim by combining three views. End-to-end engineering is the process of combining product value chains to create the commodities that consumers want. "Horizontal integration," the second idea, refers to creating new corporate ecosystems or business models. The third idea is "vertical integration," which is the process of combining many corporate systems into one (Cho, 2022). This may entail combining a shop floor sensor with an ERP system for adaptable production systems.

A "smart factory" is a term used to describe a facility in Korea that effectively integrates planning, design, manufacturing, distribution, and sales stages of production using IoT, AI, and big data (Cho, 2022). Production of bespoke goods in a timely and economical manner is the main goal. Korea is implementing many approaches to tackle the obstacles presented by Industry 4.0 (Joint Ministries, 2022). In an attempt to improve the industrial sector, the Korean government started encouraging and growing the use of smart factories in 2014. In recent years, the government has been building 30,000 smart factories with diligence.

A manufacturing enterprise's level of intelligence in setting up smart factories may be used to divide it into five stages. Level 1 is identification, Level 2 is measurement, Level 3 is analysis, Level 4 is optimisation, and Level 5 is customisation. To achieve system and process criteria, manufacturing organisations create smart factories that correspond to their level of intelligence. Approximately 8,000 industrial enterprises in Korea have implemented smart factories by the end of 2018. But most of these businesses—about 80% of them—had only deployed rudimentary smart factory technology, classed as level 1 or 2 (Cho, 2022).

While Korea is implementing smart factory programmes, precise methods for identifying the precise stage at which companies want to build their smart factories are lacking. Furthermore, there is a dearth of factual information on current smart factories that may provide guidance for the creation of new ones (Cho, 2022). One of the obstacles in adopting a checklist for a manufacturing organisation using a smart factory is the use of a supplier-centered diagnostic system. Currently available models for diagnosing smart factories combine five diagnostic areas (product development, supply chain management, shop floor automation, enterprise resource management, and factory operation) with five levels (advanced, intermediate level 2, intermediate level 1, basic, and no ICT application) (Cho, 2022). The people, performance, and process characteristics of the manufacturing organisation, together with the degree of supply technology, must all be considered while building a smart factory. Furthermore, the adoption of Industry 4.0 has resulted in the use of several cutting-edge technologies in the industrial sector, including CPS, IoT, AI, and collaborative robots. As a result, a method for evaluating and diagnosing these technologies must be established.

The Korean government declared in 2018 that it planned to convert half of its small and medium-sized manufacturing companies into smart factories. With this initiative, Korea hopes to improve its industrial capacities (Cho, 2022). The government wants to build 10 smart industrial complexes and 30,000 smart factories by 2022, according to the Ministry of SMEs and Startups (2021).

By building 30,000 smart factories by 2022, the Korean government has surpassed its annual goals and effectively realised its goal of making small and medium-sized businesses (SMEs) a powerful force in the manufacturing sector. The first objective of the government's "Smart Manufacturing Innovation" strategy has been effectively met, and its purview has also been extended (Cho, 2022). Moreover, the government has increased the scope of its assistance programmes and directed its attention on raising the calibre of smart factories. The Korean Advanced Manufacturing Platform (KAMP), Digital Clusters, K-Smart Flagship Factory, and Smart Manufacturing Standardisation are some of the initiatives (Ministry of SMEs and Startups, 2021).

Proposal 1: Collaboration with Demand Companies

Collaboration and partnerships are crucial for successfully integrating and deploying skills in the manufacturing and service sectors. However, domestic supply firms are still lacking competitiveness in terms of collaborating with demand companies to offer organised products or services, as well as enhancing their existing offerings through technology

alliances (Han, 2020). To solve this problem, we need to carefully analyse demand firms and work together to develop user-friendly smart manufacturing systems (Cho, 2022). Fixing these problems would enable small and medium-sized businesses to independently expand through cooperation (Jeong et al., 2019).

Proposal 2: Improving Worker Convenience

Setting clear objectives for the development and design of smart manufacturing tools and solutions is essential. These objectives should focus on enhancing workplace convenience for employees. Prioritising solutions that improve worker convenience is crucial (Han, 2020). It is vital to investigate diverse strategic partnerships among suppliers, establishing forums for technical advancement and cooperation (Cho, 2022). Most SMEs lack the capacity to perform essential activities like marketing and market research, which are necessary for expanding internationally. Another disadvantage they face is low brand recognition (Kim, 2020).

Proposal 3: Design-Build (Turn-key)

Large enterprises with expertise in setting up smart factories can facilitate the adoption of the design-build strategy, particularly by focusing on suppliers affiliated with major firms (Han, 2020). This technique can be used to provide services throughout the entire value chain, which includes equipment manufacturing, consultation, design, machinery and software, and maintenance. Furthermore, partnering with relevant suppliers can facilitate the expansion of the company into international markets (Cho, 2022).

5. Discussion

5.1. Policy Implications of DX in for Korean Manufacturing SMEs

This research reveals that a majority of Korean manufacturing SMEs are unaware of the importance of DX while some are only getting started. It is important to tailor digital transformation strategies to the distinct attributes, obstacles, and patterns of various enterprises, as opposed to employing a standard approach to foster digital transformation throughout all domains and industries. There are also differences in how much digital transformation has occurred in different sectors and businesses (Kagermann et al., 2012). Instead of attempting a full digital transformation from the start with a strict strategy, businesses could take a more incremental approach to DX by building on their current successes.

Korean SMEs seem to have varying degrees of preparedness and goals when it came to pursuing DX. Several goals are driving the shift to digital. They consist of process improvement, product innovation, and manufacturing innovation. By carefully applying DX at the most beneficial places in the value chains of their respective industries, businesses may optimise their profits (Brodeur et al., 2021; Bui, 2021). This entails figuring out where in the value chain digital transformation may have the biggest positive effects. Different businesses and sectors have different places to start when it comes to digital transformations and further modifications (Cho, 2022). These origins may be found in fields including marketing, distribution, manufacturing, procurement, and research & development.

This study recommends that Korean policymakers should enact measures that facilitate technological innovation and offer appropriate settings and infrastructure for enterprises to integrate DX-related technologies. This will promote and encourage DX among Korean businesses (Han, 2020). SMEs must undertake policy efforts backed by institutional and regulatory measures to provide the essential infrastructure in order to expedite digital transformation. In addition, policies that facilitate the investigation and creation of tailored solutions for digital transformation must be put into place (Cho, 2022). Enhancing skills for research and development, implementing new technologies, and encouraging the expansion of workforces and platforms for digital transformation should also be the main goals of these initiatives. In summary, regulatory modifications are required to facilitate SMEs digital transition. These modifications ought to concentrate on the legislative frameworks, consultative processes, and infrastructure.

In order to foster the growth of ICT firms and improve Korean enterprises' capacity to integrate and leverage novel digital technologies, policy support is vital. This should entail aiding ICT businesses in their research and development of cutting-edge technology (Cho, 2022). AI, big data, and 5G networks are just a few examples of the many technologies that must be extensively used and integrated in order to achieve DX.

Additionally, encouraging Korean SMEs to embrace DX can help the industrial ecosystem as a whole to develop. DX should inform the design and development of ecosystems that serve both new and old industrial companies. Supporting SMEs in learning more about DX and its possible advantages is crucial (Birkel & Wehrle, 2022). For long-term growth, SMEs require DX more than bigger businesses do. In order to undergo digital transformation and establish a positive feedback loop of development and entrepreneurial activity, startups require policy aid. To increase awareness of the advantages of DX among SMEs, it is crucial to exchange best practices across industries and businesses. SMEs may consult these best practices and learn from them (Bui, 2021). It is necessary to conduct periodic surveys in order to ascertain the obstacles and policy requirements that SMEs encounter with DX. Decisions on policy should be based on the survey results, which should also raise awareness among SMEs. A framework of advice and consultancy services for SMEs at various phases of DX should be established.

Research and development of DX technologies and solutions aimed primarily at SMEs also need policy assistance. To effectively promote bottom-up research and development, policymakers should think about putting short-, mid-, and long-term strategies or roadmaps into place (Albinson et al., 2016). This is especially crucial because it can be challenging

for SMEs to independently create their own inventions. This might entail encouraging cooperation in research and development between several SMEs. More regulatory assistance is also required to improve digital platforms and encourage servitization in the industrial industry (Cho, 2022). The emergence of service-based revenue streams in various sectors is referred to as servitization. Digital platforms that are especially made for SMEs must be developed. SMEs should also receive support in identifying and putting into practice business strategies that make use of these platforms. In the medium to long term, policymaker support will be required to promote the growth of digital platform ecosystems (Han, 2020). In addition to helping SMEs, this policy support should strengthen the institutional and legal structures that recognise and aid successful entrepreneurs.

6. Conclusions

This research reveals that a majority of Korean manufacturing SMEs are unaware of the importance of DX even as some have already started their digital transformation journey. This is mainly attributed to a lack of the capability to keep up with the speedy technological transformation. Therefore, Korean SMEs seem to have varying degrees of preparedness and goals when it came to pursuing DX depending on their investment in ICT knowledge. Several goals are driving the shift to digital. They consist of process improvement, product innovation, and manufacturing innovation. By carefully applying DX at the most beneficial places in the value chains of their respective industries, businesses may optimise their profits. This study recommends that Korean policymakers should enact measures that facilitate technological innovation and offer appropriate settings and infrastructure for enterprises to integrate DX-related technologies. Additionally, encouraging Korean SMEs to embrace DX can help the industrial ecosystem as a whole flourish. DX should inform the design and development of ecosystems that serve both new and old industrial companies.

Overall, it is important to draw emphasis on the concept of data sharing, which enables Korean manufacturing SMEs to benefit from digitization's vast potential, even with their limited financial resources, technical know-how, and IT resources. Emphasis is also drawn to the connection between establishing a separate data platform and fostering innovation in the field of smart manufacturing. Furthermore, by examining the strategies employed by these two countries, six potential implications for South Korea's manufacturing industry can be identified. These implications can guide the development of the country's current smart manufacturing innovation policy. Since South Korea's smart factory development is still in its early stages, it will require more time to progress before the findings of this study can be implemented. To further investigate the growth of manufacturing SMEs in South Korea, it is recommended to assess the effectiveness of KAMP.

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