Digital Transformation in Production Systems: A Global Business Perspective

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Abstract

Digital transformation in manufacturing represents the broad integration of digital technologies across manufacturing value chains and structures, transforming business strategies, organizational capabilities, and operational dynamics. The Internet of Things, real-time analytics, smart robotics, additive manufacturing, artificial intelligence, and automation enable increasingly self-sufficient operations. These techniques support planning, scheduling, adequate management, process control, defect prediction, predictive maintenance, and inventory control. Aid logistics and optimization. Change beyond technology adoption requires strategic transformation, plant management, workforce development, and new skills to tackle efficiency gaps and align production with evolving cost structures. Digitization yields productivity gains, cost reductions, performance improvements, efficiencies, and synergies as organizational outcomes, and stop-person value. Cross-local scale identifies North America, Europe, and South Korea as major adopters of Industry 4.0 and Internet of Things technologies. However, excessive investment, uncertain returns, and flexible capabilities hinder adoption in emerging economies. Overall, the composition shows several known country-wide pathways and limited commitments, indicating that the creation of virtual transformation is multifaceted and requires context-sensitive techniques for sustained and aggressive performance.
Keywords: Digital Transformation, Production System, Global Business

1. Introduction

Digital Transformation in Production Systems: A Global Business Perspective. Digital transformation is driving fundamental changes in production systems, business practices, and competitive dynamics, yet it remains poorly understood and inconsistently addressed. What are the salient aspects of this transformation, and how do they vary across production settings? To advance knowledge, this study characterizes the nature, scope, and impact of digital transformation on industrial production, with a special focus on the implications for global business. Digital transformation in production refers to the extensive and widespread integration of digital technology across production value chains and production systems. The key features of such transformations are an increase in the capabilities for digitizing production and communications, as well as enhanced connectivity through additional physical and digital links. The study adopts the perspective of global business, with a primary focus on advanced manufacturing and processing industries. At the methodological level, the analysis is open to a wide range of scholarly contributions and uses various types of evidence, including technical, economic, financial, and organisational information; illustrative models and frameworks; and cross-regional comparisons of general trends. Institutions are positioned centrally in the global business perspective of the study, which examines how firms sense, react to, adopt, and discuss digital transformations and their broader ramifications.

Digital transformation is a far-reaching megatrend reshaping the technologies, organisation, and global industrial socio-economic footprint of production. Worldwide, advanced manufacturing and processing systems are evolving towards higher degrees of digitisation and connectivity. Nevertheless, adoption is uneven, restricted to limited sectors and yet maturing only in a few regions. Digital transformation is broadly defined as widespread digital technology adoption across production value and operational chains; a tighter coupling of physical-to-physical and digital-to-digital activities through technology, software, and decision-making decentralisation underpins this change (Qorbani & Groesser, 2020). Digital production pervades the global economy to various extents, from fully physical systems to more entire regions, the technology round-off stage, ample infrastructure-complemented domains, and highly automated orwellian schemes; applications cross maturity thresholds from never-heard-of fragments to secured-configured settings (Von Leipzig, et al., 2017).

2. Theoretical Foundations of Digital Transformation in Production

Digital transformation denotes the profound changes brought about by digitization across economic systems and business functions (Wang, Wang, & Wang, 2024). Although digitization—the use of digital technologies to enable a company's existing activities—originated in functional areas such as marketing, sales, product development, finance, and accounting, it now influences the entire organization and its stakeholders.

Production digitization occurs when a business applies digital technologies to its production system (Qorbani & Groesser, 2020). Within this study, a production system refers to a collection of interconnected elements that work together to transform inputs into outputs. This collection includes resources in the form of materials, personnel, warehousing space, and machinery; activities such as material handling, assembly, and coating; product types produced; and information concerning production schedules, inventories held, and quality levels.

This study will assess production digitization and its impact from a global-business perspective because production represents the largest business function worldwide and the foremost contributor to labor compensation. For purposes of this analysis, a global business involves multinational firms with operations in more than one country, transnational firms serving cross-national markets, and domestic firms constrained to one nation but whose capabilities, technologies, and information originate from elsewhere.

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2.1. Definitions and Scope

Digital transformation provides opportunities for firms, yet there is no consensus on the term and its implications for production systems. Digital transformation focuses on redefining a firm's value proposition through digital technology, changing management and business models, while digitization, digitalization, and other concepts refer to enabling or improving value generation (Wessel, Baiyere, Ologeanu-Taddei, Cha, & Blegind Jensen, 2021). Production systems encompass processes and technologies that convert inputs into outputs, structuring physical, information, and financial flows across functions and entities. Automated production systems and cyber-physical systems provide a narrower interpretation; nevertheless, digitization of production represents the most mature stream of digital transformation today (Gon\ue7alves Machado, Kurdve, Winroth, & Bennett, 2018). Global business perspective relates to the integration of economic, technological, competitive, and market developments across countries; increased interconnectedness and supply-chain internationalization make it relevant for production strategy.

The term "digital transformation" lacks a universally accepted definition, as do closely related concepts such as "digitization," "digitalization," and "digital transformation." Digital transformation refers to a shift in value proposition enabled by digital technology, leading to a new firm identity. (Mele, Capaldo, & Secundo, 2024).

In contrast, digitization digitizes existing offerings; digitalization offers existing products through additional digital channels; and digital transformation primarily modifies support for an unchanged value proposition. For the purposes of this study, two specifications are included: digital transformation occurs within a holistic view of business and is distinct from business change enabled by ICT. (Evans, Miklosik, Bosua, & Qureshi, 2022).

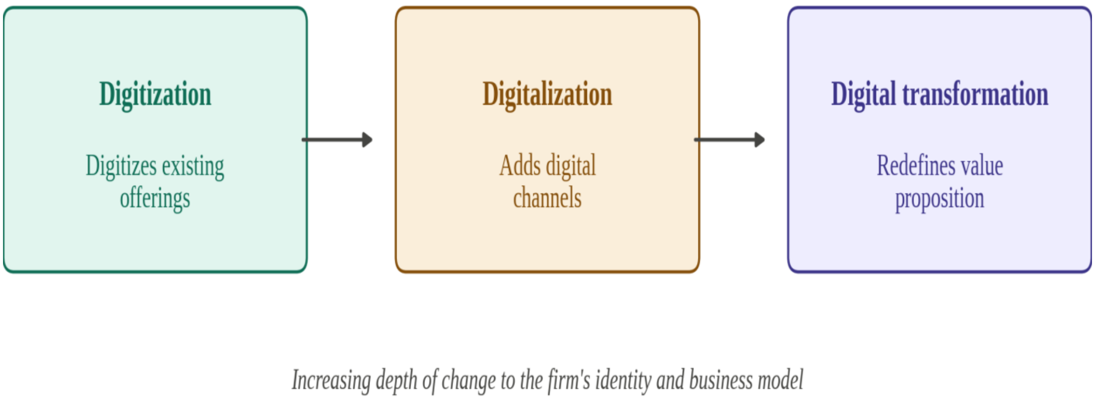

Figure 1. Spectrum from digitization to digital transformation.

Accordingly, the term "digital transformation in production" describes an interrelated stream that focuses on the production function. Production systems comprise an established field of theory and practice and encompass processes, technologies, operations, and solutions to generate goods, parts, components, or products. A broader definition includes product, process, organizational, contribution, and business model dimensions, at firm, division, and site levels. Digital transformation thus refers to a substantial shift that modifies how production contributes to the firm's overall value proposition. (Zhai, Yang, & Chan, 2022).

2.2. Conceptual Frameworks

The aim of this research is to map the conceptual landscape of digital transformation in production systems. Digital transformation encompasses extensive change driven by emerging technologies that converge the physical and digital worlds. Within global manufacturing, the key elements of the transformation are smart production systems and modern production technologies. Production systems comprise assets, processes, and rules that transform physical inputs into outputs. Modern production technologies, including the Internet of Things, advanced robotics, additive manufacturing, and artificial intelligence, shape the capabilities and organization of production systems. Five prominent theories and frameworks—industry 4.0, smart manufacturing, digital manufacturing, smart factories, and the industrial Internet—have been proposed to conceptualize the transformation in manufacturing. However, the underlying constructs are poorly articulated, preventing coherent mapping of the theoretical landscape (De Paiva Pereira, 2018). A comprehensive approach is needed to articulate more systematic and coherent theoretical constructs and to map the theoretical landscape of transformation in production systems.

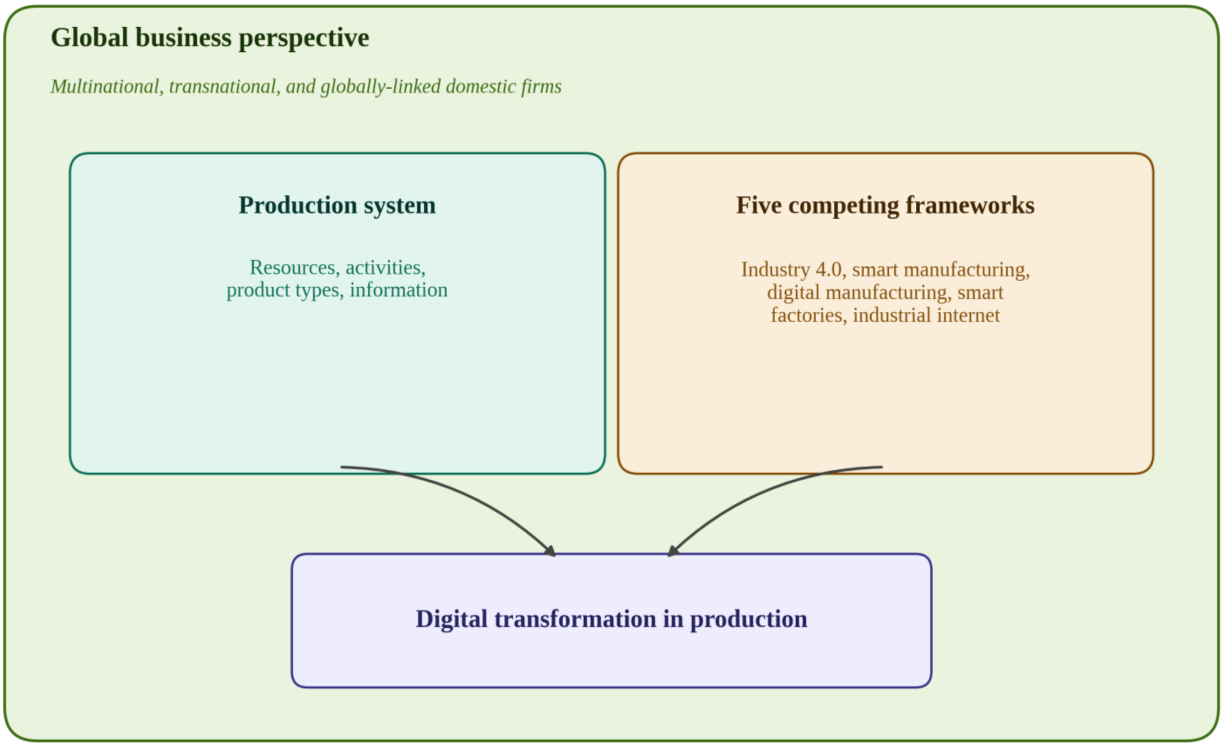

Figure 2. Production systems and the five competing frameworks within the global business perspective, converging on digital transformation in production.

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3. Modern Production Technologies and Enablers

Digital transformation in production technologies is driving a global change in manufacturing and goods delivery. The transformation is sensitive to changes in products, customer demands, and regulations. Four technologies enabled by the Internet are identified as the most important drivers of this transformation. (Jin, Wang, Luo, & Guo, 2024).

The Internet is transforming production systems and economic activity worldwide. This transformation is linked to the global scale, speed, and magnitude of Internet infrastructure buildout. Three sectors of economic activity can be defined: agriculture, manufacturing, and services. All three sectors are experiencing transformations at the global level. For example, agriculture is becoming much more intensive in the use of data. Data is being used to make Smart Pesticide decisions, to make planting decisions based upon evolving climate scenarios, and even Genetic modification is enlisting the Internet to enhance productivity through better continuous monitoring. In services, intermediary functions such as retail and banking are disappearing in a global digital barter on the Internet. Goods are moving faster than people. Distribution of products and services is becoming global and instantaneous. These changes bring increased prosperity, but a limited number of parties are winning the profits. In agriculture only seed and chemical factories, data and software firms are profiting on the value chain and shifting all risk to the farmers (Oliveira & Afonso, 2019).

The enabling technologies for digital transformation in production have become broadly recognised as: the Internet of Things ; Real Time Analytics ; Smart Robotics ; Smart Additive Manufacturing ; and Artificial Intelligence & Machine Learning. The Internet of Things has become a widely used term to cover a single or combined functionalities of different types of devices that measure, monitor, track and control movement of goods, flow of materials, control of equipment and machine functionality to support enhanced decision making processes. Examples of such devices include Imaging devices, RFIDs, Temperature, Pressure, Humidity sensors, GPS, Chemical, Gas Detectors, Vibration, Noise, Light and Proximity sensors (Qorbani & Groesser, 2020). One of the new paradigms for the implementation of IoT is in the so-called Smart Factories. Inputs and outputs of goods, flow of materials, ability and status of equipment and machines can be used to measure overall equipment effectiveness over time and provide information that enhances the integrity and Quality of the product.

A smartphone that is used in production has the potential to become a multi-functional device that provides information on quality, and the needed work during production or at the next station. In such set-up data flows back and forth between worker, material, machine and system at a high frequency. The combination of visual, audio and light data collected by a smartphone can also lead to enhanced Decision Making in planning and scheduling. Feedback loops are shortened and decisions are made more accurate, faster once they have been taken. (Chen, Lee Kong, & Kan, 2023).

3.1. Internet of Things and Real-Time Analytics

Digital transformation in production systems advances through the Internet of Things and real-time analytics (Belli, Davoli, Medioli, Marchini, & Ferrari, 2019). The foundation of the transformation is to be connected to an information and communication technology (ICT) platform that supports all the production resources in the factory. The objective is to collect the current status of where the resources are, what is produced, and how it is processed at fixed intervals to flow data and determine when decisions should be made. At that time, the data from various resources become critical information for decision-making. Collecting production resource status provides valuable data related to the production process, which is either time-based or quantity-based. Decision-making usually occurs when a fixed amount of data is accumulated, which is not always the right timing since the data for analysis may be too short to support a good decision or too late to handle an upcoming event. (Brauner, et al., 2022).

3.2. Advanced Robotics and Automation

The enhanced capabilities of modern industrial robots and production automation have augmented the flexibility and productivity of production systems, thus allowing manufacturers to effectively respond to shorter product life cycles, greater variability in product demand volume and variety, and increased emphasis on sustainability—yet a systematic assessment of currently available robotic, automation, and collaborative robotic technologies and their capabilities pertinent to improved production processes is lacking (Sanneman, Fourie, & A. Shah, 2020). Digital transformation is fostering a new generation of automation to augment workforce efficiency, address labor shortages, boost productivity, sustain competitive edge, and enable hybrid flexible and autonomous production operations (Ivanov, 2020). The incorporation of Industrial Internet-of-Things (IIoT) and real-time data analytics into production processes has enabled advances in data generation, connectivity, modelling, and algorithm. These advances, along with new robotic systems such as collaborative robots (cobots) and autonomous guided vehicles (AGV), and innovative 3D printers and flexible processes, further support the shift toward hybrid flexible and autonomous production scenarios and enable unprecedented production capacity and capabilities. (Tenakwah & Watson, 2025).

3.3. Additive Manufacturing and Flexible Manufacturing

Additive manufacturing (AM), also known as 3D printing, enables the fabrication of geometrically complex parts layer by layer using various materials. Its primary benefits include design freedom, mass personalization, rapid prototyping, decentralised production, and improved supply-chain resilience. AM allows the production of fully functional parts directly from computer-aided design (CAD) files, parallel part fabrication, and the integration of multiple functions and materials into a single part. Scheduling flexibility lets firms rapidly accommodate changes in demand or specifications. AM reduces material waste, supports recycling, facilitates the use of alternative feedstock and the design of lighter products, and enables in-situ repair (Oberg, Shams, & Asnafi, 2018).

Together with flexible manufacturing systems, it helps satisfy the need for greater product variety, shorter life cycles, faster delivery, and more customer involvement caused by increasing market complexity and volatility. Integrating AM with flexible manufacturing enables organisations to respond quickly and effectively to market challenges and play a proactive role in shaping market evolution. (Fenta, Tsegaye, Abere, & Tefera, 2025).

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3.4. Artificial Intelligence and Machine Learning for Production

Artificial Intelligence (AI) and Machine Learning (ML) have increasingly gained prominence within the global manufacturing landscape. Their application within production systems has garnered considerable attention from the industrial community. Notably, the recurring themes of ‘smart manufacturing’, ‘Industry 4.0’, ‘sustainable development’, and ‘big data’ are integral to ongoing discussions on the importance and benefits of AI and ML technologies.

The advent of ‘Big Data’—characterized by large, complex, and rapid production data generation—has further spurred the development of intelligent systems. Manufacturing plants continually gather data through sensors embedded in equipment and systems connected to the Internet of Things (IoT). The swift evolution of AI and ML paradigms has made them valuable tools for intelligently processing this data and deriving meaningful insights. Their application encompasses various functions, including production planning, scheduling, quality control, process monitoring, fault diagnosis, predictive maintenance, inventory control, and logistics optimization. The profound impact of AI and ML on production, manufacturing systems, and human well-being remains widely recognized (Frankó, Hollósi, Ficzere, & Varga, 2022); (Wan, Li, Dai, Kusiak, Martínez-García, & Li, 2021).

4. Organizational and Strategic Implications

The imperatives of modern and rapid digital transformation compel firms to reframe their design and strategy at the highest levels within the organization. As many experts advise, establishing a digital transformation strategy that supports broader business goals increases the likelihood of success (Qorbani & Groesser, 2020).

The foundational stages of establishing an overarching strategy involve the determination of strategic objectives and the corporate portfolio that will foster enduring competitiveness. Concordantly, identifying the target state for digital transformation resides among the primary objectives. Significant sectors of businesses that need to adapt the corporate governance structures for such strategies include the alignment of incentive systems with long-term strategic goals, the design of an effective collaborative decision-making process among executive leaders, and the assignment of decision rights at divisions and business units that are directly involved in the overall transformations. (Baslyman, 2022).

Figure 3. From strategic intent to redesigned ways of working.

Digital transformation demands profound rethinking of how work is done through changes in both fundamental processes and organizations. In organizational design, key determinants include holacracies, decision flexibility, customization, and batch size (Von Leipzig, et al., 2017). The talent and skill base of an organization often needs to adapt accordingly as the worker role within an enterprise changes in response to evolving fundamental processes. The industrialized supply of professional services and the closing of global skill gaps suggest that skills change may occur relatively quickly, albeit with significant reskilling efforts. A discourse on macro-economical and societal perspectives accompanying the digital transformation may engage the business community more readily on the general directions of change that affect their operations and value creation.

4.1. Change Management and Governance

Digital transformation has a substantial impact on the development of change management and governance within industrial production systems. Adopting Industry 4.0 technologies necessitates a reevaluation of previous operating principles, models, and structures, as production processes must evolve to remain relevant in rapidly changing competitive environments (Qorbani & Groesser, 2020). Implementing digitization introduces new fields of activity that demand consideration from change management and governance perspectives, while existing frameworks are no longer applicable (Csedo et al., 2018). Digital transformation alters customer roles, from passive consumers to active producers involved in developing services widely termed “prosumers.” Business models requiring planned production may collapse as independent entrepreneurs, start-ups, and other non-incumbents challenge conventional supply chains and threaten existing products (Von Leipzig, et al., 2017). Customers can produce their own energy even when the initial purchase is still feasible. The growing trend toward customer-included business models puts additional pressure on industrial players; fulfilling rising demands incurs high costs. In fiercely competitive environments, the necessity for quick adaptation offers opportunities to rethink products, services, and value delivery.

Governance is vital to aligning the firm’s strategy with Industry 4.0–driven change and for directing broad-scope initiatives beyond the control of a single function or decision-maker. Digital transformation is broader than merely introducing new technologies. Change management involves identifying drivers needing change within production systems, transforming those drivers into actions requiring additional changes, and understanding relevant timeframes and activities governing transformations between the current and future states. An engaged management board remains indispensable for fostering change. (Yaqub & Alsabban, 2023).

4.2. Talent, Skills, and Workforce Transformation

The fourth industrial revolution has created a significant skills gap between workers’ current capabilities and rapidly evolving job roles in manufacturing, requiring new approaches to talent development (Whysall, Owtram, & Brittain, 2019). The fourth industrial revolution, characterized by the fusion of physical, digital, and biological technologies, is transforming production systems and offering competitive advantages (Ramzi, Ahmad, &

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Online ISSN 2771-1153

Zakaria, 2019). New skills such as app development, data analysis, and drone operation have emerged, highlighting the challenge of keeping pace with change.

The new era in manufacturing creates higher-paying, skilled jobs alongside the elimination of unskilled roles. Industry-wide staff shortages can be addressed by increasing the skills and capabilities of existing employees and by attracting talent from other sectors. Learning environments that promote creativity and experimentation and incorporate hands-on experience are essential to creating such staff. Aligned with corporate strategy, middle managers' understanding of strategic direction and their support for change initiatives are critical enablers of transformation. (RISI, 2025).

4.3. Cybersecurity, Risk, and Compliance

Digital Transformation in Production Systems: A Global Business Perspective. Modern manufacturing and industrial production systems are rapidly changing through the adoption of advanced digital technologies. These in turn create systems of Cyber-Physical Production (CPPS), in which physical production resources are integrated with information systems and can adapt and optimize production in real time. From a wealth of practitioner-focused literature, eight key technologies have been identified as drivers of CPPS evolution. Additive manufacturing (AM) is an efficient method for customizing products to satisfy increasingly diverse customer demands, enabling a single economic process for low-volume production in a high-demand market, and supporting customization. Flexible manufacturing systems (FMS) are collections of machines, robots, transportation carriers, storage systems, and other devices integrated by a centralized control system, allowing quick product changeover and production rate adjustment. Cybersecurity measures are critical when opening systems to remote access and ensuring production continuity. Compliance measures are often mandated by regulations and standards but also significantly support production continuity. The following sections address these technologies and their interplay across organizational domains. (Abdelkader, Amissah, & Abdel-Rahim, 2024).

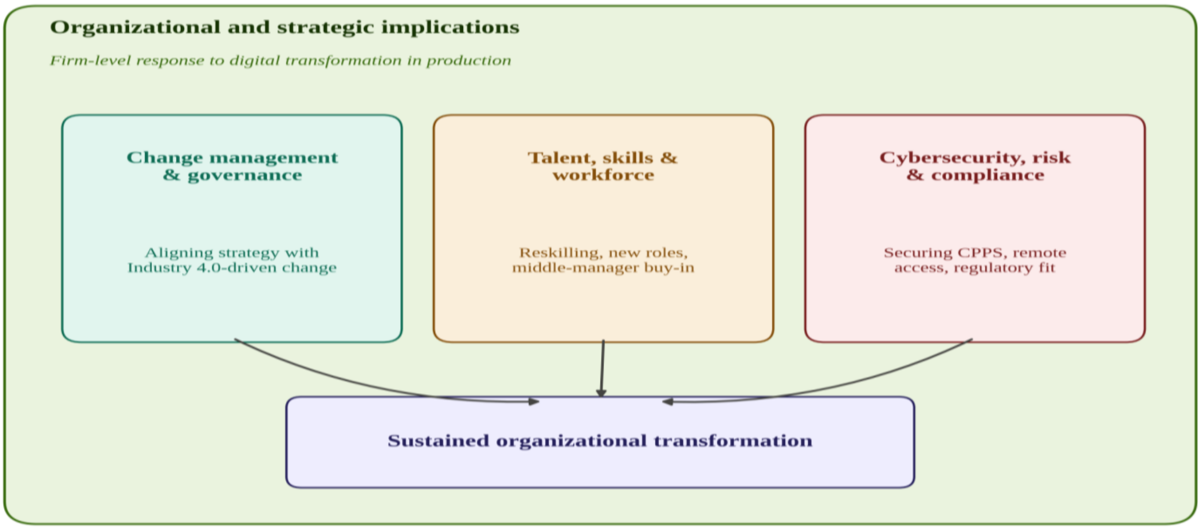

Figure 4. Change management, talent, and cybersecurity as three pillars of organizational and strategic transformation.

5. Economic and Competitive Impacts

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In the Finance and Economics background of the global practice of digital transformation in production systems, it is possible to identify the most distinct economic and competitive impacts on firms and ecosystems in a Business Case approach. Digital transformation in production systems drives significant changes in the economy that can be observed in a Business Case ranging from North-America and Europe to South-East Asia through to Africa.

Digital transformation in production systems boosts productivity and efficiency, resulting in a higher output-to-input ratio, reduced costs, and improved profitability. Furthermore, an improved product mix is achieved as shifts in operating expenses have occurred with labour and related costs falling and repairs, maintenance and consumer service reducing, being counterbalanced only by the rising costs of external contractors. For investments, there is a switch from capital expenditure and towards operational expenditure, with advantages on less debt load relative to complete-out planning, with respect to balance sheet sustainability and with speedier return-on-investment cycles (Wang, Wang, & Wang, 2024). With early signs of technology constraining further unit-cost reductions, the major opportunity now is to generate new products, services and other offerings. Enabling co-innovation on digital platforms potentially becomes a key factor of competitiveness. In Europe, there already is an active co-creation ecosystem at the process-specialization level that participates intensively in platforms operated or co-operated with product-leaders alongside partnerships on advanced-design technologies of neighbouring domain-areas (Mastilo, 2017).

5.1. Productivity, Efficiency, and Cost Structures

The economic impact of advanced technologies on manufacturing is understood in terms of labour productivity, overall productivity, and total factor productivity. Different types of digital technologies "accumulate" in different ways, prompting differing adjustments in capital and labour input and leading to differing economic effects (Qorbani & Groesser, 2020). Digital technologies first introduced into manufacturing, such as advanced robotics and additive manufacturing, differ in terms of their cumulative effect on manufacturing. Productivity improvements accrue gradually but materialize from their earliest phase, lessening overall uncertainty involved in Digital Transformation. Innovations with exponential, stage-gate effects, such as cloud computing and Artificial Intelligence, come later and involve greater uncertainty (Črešnar, 2022). Conversely, the Digital Transformation of a firm's entire value chain does not necessarily require individual, digital transformation in production. The design of new products or triggers for new subsystems within production itself may suffice. Digital Transformation allows increased production freedom as more variables are involved and more elements—originally excluded—become relevant. Changes in the information environment produce equivalent modifications in process structures, functions, and potential solutions to reflect a new design of a system operating on another level.

Print ISSN 2771-1161
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5.2. Innovation, Co-Creation, and Ecosystem Play

While automation previously revolutionised manufacturing systems through mechanisation, electronics and control technology, today a different perspective has emerged. Instead of focusing on the new possibilities that a certain technology opens up, attention is directed towards the end-user process and the value that the system delivers to the end-user. Technologies are regarded only from the perspective of their specific ability to add value to this end-user process (Von Leipzig, et al., 2017).

The accumulation of technology has increased the complexity of machine and system configurations and their usability. Problems inherent to incorporating new functions beyond already extensive systems into existing manufacturing systems arise. Companies are stuck trying to decide whether or not to add new functionality that cannot be realised without overly complicating these already complex systems (Chehri, Zimmermann, Schmidt, & Masuda, 2021).

Traditional manufacturing systems have gradually evolved into those that consist of various types of manufacturing equipment and systems, controlling them requires human operators to determine a combination of parameters for the overall system. Such considerations have made it difficult to achieve sustainable innovation. Emerging new types of production systems in addition to the existing conventional production systems should provide a wider, new socially oriented value on the manufacturing side of society (Deng, 2018).

5.3. Investment, ROI, and Financing Models

In the manufacturing and service sectors, the realisation of digital transformation is largely influenced by the digital maturity and capability levels achieved in each industry. A comparison across business and manufacturing industries, geographies, and the adoption stage provides useful insights into the implications of the global digital transformation process. In recent years, financing conditions for product, process, and digital transformation investments have diverged significantly among the different regions. Industrial businesses restrict their investments to technologies that complement the existing production capabilities, productivity improvements, and measures that mitigate production waste. In production systems, investments, financing conditions, and digital-transformation maturity levels still differ, sometimes even markedly, between the countries of North America, Europe, and Asia-Pacific despite the progressive global rollout of digitalisation since the beginning of the 1970s. Due to diverse local and global industrial ecosystems, such as business culture, company size, digital-infrastructure maturity, per-capita income, stakeholder conditions, and the adoption of Industry 4.0, the United States, Canada, and Western Europe continue to lag behind the pioneering nations of Japan and Germany in some digital-subjective investments (Von Leipzig, et al., 2017).

6. Case Studies and Cross-Regional Comparisons

The broader context surrounding Industry 4.0 and its associated descriptors (Smart Manufacturing, Industry 4.0, and the Fourth Industrial Revolution) demonstrates parallels among regions at similar levels of adoption. In particular, North America and Europe have emerged as early adopters of Industry 4.0 and IoT technologies. Data from Surveys conducted in 2015, 2018, 2019, and 2021 across a few markets confirm that these regions, together with South Korea, have consistently maintained the highest levels of preparedness for Industry 4.0 (Qorbani & Groesser, 2020). Even among early adopters, however, heterogeneity exists in the underlying factors that influence the global proliferation of these domains within the production system.

A complementary trend emerges in the Asia-Pacific region, which has witnessed a continued emphasis on scaling existing operations and enhancing production and supply chain resilience. Accelerators cited by firms operating in the region include improved capabilities for production scheduling, supply chain management, real-time monitoring, workflow automation, remote maintenance, and data-driven decision-making for multiple processes, ranging from production line adjustments to material quality use (Wang, Wang, & Wang, 2024). Finally, firms situated in emerging markets encounter different constraints than their counterparts elsewhere. Instead of focusing exclusively on the acceleration or maturation of Industry 4.0 adoptions, strategically relevant national drivers may also promote the simultaneous build-out of local data and digital technologies, supply chain knowledge, and flexible production methods. Because current knowledge and transfer mechanisms largely favour technology and data-oriented components, gaps according to region and industry remain.

6.1. North America and Europe

With the development of Industry 4.0 and the ascent of smart manufacturing, global business paradigms have evolved substantially. Production systems are undergoing profound digital transformation, impacting firms' competitive positions and the nature of global production and supply networks. Digital transformation refers to process and organizational changes that result from the pervasive uptake of advanced digital technologies, changing the relationship between business processes and business capabilities (Qorbani & Groesser, 2020). While manufacturing and supply chain management legitimize the relevance of digital transformation as a distinct domain, the emphasis on the global aspect highlights how transformations in production systems have far-reaching competitive and strategic implications.

A global business perspective addresses the influences of systematic internationalization on companies' strategies in an interconnected world and elucidates their strategies for responding to the chains originating from the global environment and pervading production activities (Von Leipzig, et al., 2017). The comprehension of digital transformation in production systems is therefore enriched by identifying the effects of global factors on companies' digital transformation and the interactions between the global environment and performance, competencies, and strategies for production activities, digital transformation in production systems, global production systems, and global business perspectives across regions.

Digitalization of industrial activities in North America and Europe has led to significant transformation in production and supply chains, challenging traditional business models. The

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shift enables new roles for prosumers, who not only consume but also produce and design products, disrupting top-down approaches. In the electricity sector, decentralized models where consumers generate and sell excess electricity challenge utility companies. Companies face intense competition, increased customer demands, and the need for fundamental operational changes, which involve risks and costs. Addressing these challenges requires understanding complexities through multiple data collection methods. (Bigliardi, Filippelli, Petroni, & Tagliente, 2022).

Digital transformation threatens and offers opportunities to reinvent business models. Companies often struggle with how to start digitising; models based on continuous improvement and triggers for innovative thinking have been proposed and validated in the German service sector. Digitisation has significantly changed customer behaviour and expectations, compelling organisations to proactively anticipate future needs to remain competitive. Embracing smart services and production focused on customer value creation is crucial for future manufacturers. Companies ignoring these changes risk disappearing altogether. (Pech & Vrchota, 2022).

6.2. Asia-Pacific

Digital transformation continues to change the nature of production systems and, with it, the strategic agendas of firms and regional production ecosystems. A regional study of the Asia-Pacific region shows that the highly interconnected value chains that run between countries in the region have been affected by the recent disruptions caused by the COVID-19 pandemic, as seen in sectors ranging from pharmaceuticals to electronics. Many companies have sought to mitigate these disruptions by scaling up digital transformation initiatives, which is increasingly viewed as a key enabler to build stronger resiliency in production systems. Digital platforms that allow design, production, distribution, and consumption to be connected with real-time data-sharing among partners within a country or between countries have emerged as an important practical solution across industries. (Kumar, Sindhwani, Behl, Kaur, & Pereira, 2024).

Participation in digital platforms is uniquely high in the Asia-Pacific region, both in factory-to-factory and enterprise-to-enterprise domains. Various digital capabilities can be deployed to enable production platforms, depending on factory and enterprise profiles. For example, advanced data analytics enables industrial-scale production platforms, while the combination of design data management and low-code-no-code interfaces allows small-scale, multi-part production platforms and open collaborations to flourish regardless of enterprise size. Platforms that focus on operations are also being complemented with capabilities to capture customer preferences, connect directly with customers, and enable collaborative and open co-creation with downstream partners (Wang, Wang, & Wang, 2024).

6.3. Emerging Markets

The high investment level, coupled with the relatively low rate of economic return, has generated an increasing tendency towards financial mistrust of production digitalization by emerging-market actors. Digital transformation has been perceived as a compulsory component of any industry by firms operating in developed regions, prompting a tendency for these firms to invest monetarily in the technology. In contrast, a diminished inclination toward change has emerged among exporting companies in emerging markets such as Brazil, Mexico, South Africa, Colombia, and Argentina. The rationale stems from limited value-creation opportunities owing to the low technological content present in most of their exported products (Wang et al., 2024). Observers have recognized a further disadvantage in relation to the application of digital technology to enhance production efficiency, with digital transformation being predominantly regarded as an opportunity for exporting companies operating in high knowledge-based industries (Qorbani & Groesser, 2020).

7. Conclusion

The synthesis of previous chapters highlights an intriguing methodological paradox that emerges when we delve deeper into the broader analysis of digital transformation within production systems. On one hand, the remarkable advances in technologies, enhanced capabilities, and the development of various frameworks strongly suggest a trend towards rapid adoption and transformation across countless firms, diverse industries, and different geographies; indeed, cross-regional comparisons of maturity provide compelling supporting evidence for this assertion. On the other hand, extensive studies indicate a limited understanding and a worrisome low commitment to these transformations in many countries, particularly those that are just beginning to enter the adoption phase; in fact, a detailed analysis of specific regions underscores the significant diversity of trajectories that can be observed throughout the world. This complexity reveals the multifaceted nature of digital transformation and highlights the necessity for nuanced interpretations of these varied patterns of adoption.

To effectively conceptualize this duality, the notion of production systems adopts a much broader, more systemic perspective, encompassing an array of all processes, practices, and IT systems that are necessary for the sustainable creation of goods and services designed to fulfill a market need. As the evolution toward sophisticated global production systems gains significant traction, the challenges that are posed by the differing advancement velocities, varying frameworks, and often insufficient knowledge bases are becoming increasingly prominent. This is particularly the case for firms that are striving to achieve a suitable regional balance among their production and operational footprints in a complex and interconnected world.

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