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Technology, Innovation and Business Transformation: An Industry 4.0 Perspective

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Abstract:

Purpose: *This study is intended to investigate different factors related to technology innovations and particularly business model innovations and particularly its impact on small and medium sized enterprises to find out its relevance and possibilities of transforming the business according to Industry 4.0 technology requirements.*
Design/Methodology/Approach: *Theoretical analysis and research model has been used to discuss the concepts and the literature study. This paper is primarily based on research journals, articles and relevant websites that provides the most updated information on the chosen topic.*
Findings: *The technology innovations related to Industry 4.0 have different impact on different enterprises depending on the size and the resources it enjoys both internal and external. The fourth industrial revolution is transforming many industries globally. Big companies have potential as well as resources to adopt Industry 4.0 technologies and innovations, however, the small and medium sized businesses still need to develop and innovate their business models to be competitive in the international markets.*
Practical Implications: *This paper is helpful in conceptual understanding on different forms of innovations in businesses, including technological and business model innovations while adopting Industry 4.0. The research findings provide an insight for future investigation in this direction.*
Originality/Value: *The systematic literature analysis and the research performed in this study is useful for minimizing the research gap related to Industry 4.0 and enterprise level innovations.*

Keywords: *Industry 4.0, Small and Medium size Enterprise (SME), Business Model Innovation (BMI).*

JEL codes: *L1, L21.*

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1. Introduction

The technology innovations related to Industry 4.0 have different impact on different enterprises depending on the size and the resources it enjoys both internal and external. The fourth industrial revolution is transforming many industries globally. Big companies have potential as well as resources to adopt Industry 4.0 technologies and innovations, however, the small and medium sized businesses still need to develop and innovate their business models to be competitive in international markets.

The purpose of this paper is to investigate different factors related to technology innovations and particularly business model innovations in Small and Medium Sized Enterprises (SMEs) to find out the relevance and possibilities of transforming the business according to Industry 4.0 technology requirements. This study is primarily based on research journals, articles and relevant websites that provides the most updated information on the chosen topic. The paper is helpful in conceptual understanding on different forms of innovations including technological and business level while implementing Industry 4.0. The research findings can give insight for future investigation in this direction.

The 'Industry 4.0' concept was introduced in 2011 to represent the fourth industrial revolution by the German federal government to transform the businesses in the manufacturing sector. Industry 4.0 is one of the most trending topics recently in both professional and academic fields (Chiarello *et al.*, 2018; Liao *et al.*, 2017). The same concept has also been referred to as 'smart factory' as a synonym in which machines are interconnected with wireless connectivity and sensors, to streamline the entire production line and control to make decisions.

However, from a business point of view 'Industry 4.0' can be defined as the new platform for product firms where machines, products and processes are interconnected and integrated by using the industrial Internet of things to produce high value products for customers and the firm's internal process. The fourth industrial revolution entails not only the production process, its efficiency, and productivity, but also the ability to interconnect and make all resources including physical assets and people work together.

Industrial revolution 4.0 is disconnected from the needs of small and medium-sized businesses (Imran *et al.*, 2018), consequently research is required to ensure the long-term survival and growth of SMEs. Especially considering the specific nature of SMEs characteristics regarding Industry 4.0, require further analysis and research that helps them to redevelop or extending their existing business models. Companies must adjust their business models in response to technological developments such as Industry 4.0, nurturing opportunities and addressing obstacles that arise (Saebi *et al.*, 2016).

Companies can extract value from new technologies only through suitable business models (Chesbrough, 2010). However, SMEs need to invest in innovation activities and high-performance processes for gaining competitive advantage. The digitalization of manufacturing firms is expected to have productivity gains. At the same time, digitalization presents an opportunity for SMEs, where a less structured enterprise can

develop the capabilities very rapidly to proactively leading to business model innovation (Lindgren and Abdullah, 2013). External partners from the network can be useful for SMEs for collaboration in making product development related strategies as well as to develop innovation business model strategies.

While the Industry 4.0 paradigm, in this digital era integrates various technologies and creates opportunities and potential not only to create dynamic new products and services and to share information between different entities of the technology ecosystem (Lombardi, 2019) but also to create new innovative business models.

However, SME's specific challenges differ from those of large firms regarding Industry 4.0, therefore, SMEs need customized solution that can answer their specific challenges, but past research has primarily focused on large enterprises rather than on SMEs (Müller *et al.,* 2018). Hence, the focus of this paper is to address the topic of business model innovation (BMI) and Industry 4.0 in SMEs.

2. Literature Review

Most of Industry 4.0 concepts are focused on delivering of intelligent products and production processes by integrating modern information and communication technologies (Brettel *et al.,* 2014). Intelligent products, processes and procedures are all thus a part of the fourth industrial revolution which emphasizes on product innovation, process innovation and even business model innovations (also referred to as digital business model). It is well established that firms need to build an acceptable business model to assist their planning for interacting with impending future technological developments such as industrial digitalization within the Industry 4.0 era specially when future directions and alternatives in technology are ambiguous and uncertain (Ghobakhloo, 2018).

Moreover, enterprises face problems in a continuously changing and uncertain business environment, and innovation is a critical tool for maintaining their competitive advantage (Lin *et al.,* 2006; Trzcielinski, 2021). While according to Ramsauer (2013), traditional industries must be innovated in order for industrial nations to maintain their competitiveness and economic wealth in the long run. However, short-term productivity and long-term sustainability are both influenced by the technological advancements and emerging innovations in corporate contexts. According to most recent research made by Ghobakhloo (2018), the concept of Industry 4.0 is dependent on underlying technology trends and design principles, where 'technology trends' simply refers to the advanced digital technological innovations that aid the emergence of Industry 4.0, a new digital industrial technology.

Although product and process innovations have significant importance, studies also suggest business model innovations are essential for upcoming success (Wischmann *et al.,* 2015). Many researchers and practitioners in this context are specially concentrated on technological implications under Industry 4.0 (Burmeister *et al.,* 2016). However, it is also debated that the innovation ecosystem's structures can be self-organized or managed to produce a system of innovative products and services by forming multilayer

networks of actors with various features (Tsujimoto *et al.*, 2018). It is worth to notice that innovation is driven by experienced employees and creative university graduates but also by government support for R&D, training, and technical assistance (Rao *et al.*, 2002).

In order to sustain the technological advancements and upcoming innovations, enterprises need to learn to adopt business model transformation. In such situation the innovative aspect of an enterprise can be determined or measured by the knowledge and technology they possess. Enterprises, on the other hand, were not very interested in implementing innovation to change their successful business model and established customer relationships (Jovovic *et al.*, 2017; Trzcielinska, 2021). This is due to the fact that innovations are mostly connected to risk. Particularly technological innovations are associated with uncertainty factor at each level of its implementation.

Whereas, in the fourth industrial revolution, innovation is a crucial element which cannot be ignored especially when it is connected to the technological upgradation of the firm. However, the technological innovation risks are mostly associated to technological uncertainty, market uncertainty, lack of knowledge on innovation benefits and institutional environment. And to overcome this impediment a systemic understanding of innovation policy is essential, which should be included in the firm's strategy, and which needs a coordinated implementation.

However, mostly those organizations which recognize the necessity of constant innovation will be able to survive in a highly competitive environment (Pavlović *et al.*, 2018). On the other hand, Industry 4.0 relies on the use of digital technology to collect and analyze data in real time, delivering important data to the manufacturing system (Lee *et al.*, 2015; Wang *et al.*, 2016a). Since it is useful in improving quality, productivity as well as flexibility and can help in the production of customized products at a big scale in an efficient way while reducing resource consumption (Dalenogare *et al.*, 2018, de Sousa Jabbour *et al.*, 2018). While according to (Xu *et al.*, 2018) digital technologies incorporation into industrial activity has helped the emergence of industry 4.0 concept.

Digital technologies including intelligent sensors allow firms to extract a significant volume and variety of real-time data on factory performance and its external factors, which aids in decision-making. This merging of physical and virtual domains by using cyber physical systems (CPS) is the core of Industry 4.0 concept that leads to a paradigm shift (Xu *et al.*, 2018). It is however understood that Industry 4.0 technologies allow organizational actors, machines, and other resources to communicate and collaborate with each other in an intense manner in a production and innovation environment.

This integration of technologies with industrial actors also increases the volume and diversity of business data in the real time, apart from delivering innovative and customized digital solutions such as data-driven services and integrated platform solutions. On the other hand, Buhalis and Sinarta (2019) argues that companies try to exploit the flexible, dynamic and agile digital technologies to create innovative service offerings. Closer relationship with external partners of the organization is considered as crucial when it comes to capability development that is increasingly cognitive, analytical,

and relational. The collaboration capabilities of a firm lead to new source of knowledge, innovations and technologies that enables competitive aspect of the firm in a complex and uncertain environment (Costa and Porto, 2014; Teece, 2007). Hence collaboration capability has vital importance in a digital business environment.

However, the technological competitiveness amongst rival companies will be determined by their capability to obtain external information and connect it to their collaboration networks. This will necessitate a greater ability of the firm to organize knowledge that is spread throughout its technological network partners (Costa and Porto, 2014). The 'innovation capability is defined as the firm's ability to continuously transform knowledge and ideas into new products, processes and systems for the benefit of the firm (Yang, 2012).

Innovation is also critical for generating customer loyalty, strengthening the logistics service provider (LSP)-customer relationship, achieving competitive advantage, and improving the performance of logistics service firms (Asian, 2019; Wagner and Sutter, 2012). Developing innovation capability, innovative processes, and innovative culture, is critical in managing and mitigating supply chain risks according to (Dani, 2010).

However, Industry 4.0 solutions takes into account a complex system of interconnected digital technologies, information systems, and processing technologies that necessitates a high level of competence interdependency and technological complementarity (Dalenogare *et al.*, 2018; Reischauer, 2018; Rübmann *et al.*, 2015). Industry 4.0 innovation ecosystem, therefore, has emerged as a more ideal architecture for technology development and provision due to their distinctive nature, involving interdependency and value cocreation instead of the linear supply chain approach (Rong *et al.*, 2015).

Industry 4.0 integrates two streams of research, one relates to the industrial processes with significant attention towards smart manufacturing and other that is related to process and product innovation which aims to add value to the customers (Frank *et al.*, 2019; Wei *et al.*, 2017). In this context, small and medium-sized firms (SMEs) are the ones who can benefit the most out of Industry 4.0 innovation ecosystems since they lack the financial resources to acquire the transdisciplinary knowledge and competencies needed to build sophisticated solutions on their own (Dallasega *et al.*, 2018).

Despite the recent emphasis on Industry 4.0 (Liao *et al.*, 2017; Osterrieder *et al.*, 2019), little is known about how to systematize SMEs' efforts through the promotion of innovation ecosystems for cocreation of Industry 4.0 solutions. On the other hand, BMI is appealing towards new customers who either are not totally satisfied with current business solutions or don't have access to them (Yunus *et al.*, 2010). BMI not only engage the new consumer groups, but also targets to achieve customer loyalty using more comprehensive value offers (Enkel and Mezger, 2013).

While BMI is a cost-effective option for customers, BMI represents the "designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements" (Foss and Saebi, 2017). Innovation activeness therefore is a key factor and is needed to relate to Industry 4.0 solutions for a successful business model

innovation. However, innovation, collaboration, integration, and interoperability are considered as four main success factors in Industry 4.0. While Eloranta and Turunen (2016) claim that "IoT boosts the availability of data and expands opportunities for process optimization, collaborative value creation, business model innovation and as a result restructures the existing industries". The business model innovations are combination between structure, content and structure of innovation aiming at creating firms value (Amit and Zott, 2012; Zott and Amit, 2017). When new players enter into market, the existing and incumbent firms feels the need to develop new enterprise level capabilities and innovative business models due to the changing market requirements and competition.

A digital transformation therefore depends up on how firms innovate their current business model. Business model innovations are also a part of implementation strategy in the context of sustainability for the incumbent firms (Massa and Tucci, 2014) and has the objective to create value and it is part of strategic implementation in strategic management framework (Amit and Zott, 2010; 2012; Zott and Amit, 2017).

However, the integrated digital infrastructure related to Industry 4.0 is estimated to deliver faster industrial processes, improved efficiency, boost economic growth and significantly change the profile of the existing workforce (Reußmann *et al.*, 2015). Even though this new technology-driven wave of innovation is positioned as bringing significant disruption to the manufacturing industry, a lot of barriers still exist for many sectors and specially for smaller-scale manufacturers with adaptation challenges when compared to big companies (Mittal *et al.*, 2018; Sommer 2015). Examples can be limited managerial knowledge of the Industry 4.0 concept, workers/fears to be replaced by machines, distrust in new technologies and lack of investment resources

3. Industry 4.0 and Enterprise Level Innovations

3.1 Industry 4.0 and Innovations

The expectations from Industry 4.0 in terms of its innovation impact is strongly linked to its interconnected technologies. The growing popularity of Industry 4.0 technologies is due to fact that it can be seen as a smart recombination of existing technologies with new technologies and their application to the manufacturing environment (Trappey *et al.*, 2016). It is also considered as the new paradigm shift in the industrial production.

However, many studies have proven that Industry 4.0 has a positive influence on production process and services, and significantly improves performance (Imran *et al.*, 2018; Nawanir, 2016). In this context, innovation is greatly connected with industry 4.0 in the last decade where mobile, cloud, social media, and big data combination created new concept for industrialization process and has significantly shifted the market into new era of competition and differentiation of products (Geiger and Sá, 2013) which leads to innovation-based economy where data, knowledge and IoT's are at primary focus.

An integrative role for these different technologies can be played by Blockchain technology, which can enhance the efficiency of its own Industry 4.0, security and

provenance regarding related data on goods, assets and operations, and aims to integrate heterogeneous systems, manage commercial transactions and support the traceability of its own assets (Bueno *et al.,* 2020). While the new industrial revolution has been linked to factors such as innovation, intellectual property rights, smart technology, and access to knowledge (Geiger and Sá, 2013). Industry 4.0 can also be described as an umbrella term which encompasses variety of latest concepts, and numerous disciplines which are linked within the industry to transform the business operations (Lasi *et al.,* 2014).

With the combination of intelligent devices and machines, there is a possibility of lowering the production costs, increase flexibility, quality, and speed of production by making use of knowledge-based solutions and increasing enterprise capabilities. This leads to a new phase of automation in the firm that enables innovative and more efficient processes, products, and services. However, due to the changing role of customer behavior in the production process, firms are expected to modify and bring changes in their existing business models with new innovations to improve responsiveness towards customers.

Moreover, customers have become more outcome oriented (Geiger and Sá, 2013), which needs new approach towards representing new business models. For example, the necessity of increasing the interaction between the firms and consumers in the online social networks, and how to model these online interactions for low-cost social media marketing is crucial. The implementation of Industry 4.0 in manufacturing firms helps in boosting production capabilities, improving efficiency, and shorten the breakout times.

Moreover, the digitization process enables the transformation of business models using intelligent technologies such as artificial intelligence (AI), Internet of Things (IoT), robotics and machine learning, etc. Researchers have also confirmed that digital transformation of firms has considerably positive impact on productivity and performance on macro level (Bughin *et al.,* 2019; Shahbaz *et al.,* 2019). However, the so-called 'digital transformation' and the connected area of 'Industry 4.0′ are about to change various business models and organizations thoroughly (Büyüközkan and Göçer, 2018).

Whereas, to successfully implement innovations within a supply chain, a clear communication strategy with a changed mindset with regards to those innovations among all involved partners in the supply chain is required (Sabri *et al.,* 2018). Furthermore, the transformation needs to be implemented as a long-term process with cyclical, successive phases consisting of multiple trials.

3.2 Industry 4.0 and Business Model Innovation in Small Businesses

It has been noticed that coercive manufacturing firms are often influenced by process efficiency and process innovations while adopting industry 4.0 technologies. However, to fully realize Industry 4.0's potential, new business models must be explored in addition to process efficiency (Frank *et al.,* 2019; Müller *et al.,* 2018). As mentioned by (Chesbrough, 2010) companies can extract value from new technologies only through suitable business models. For example, the potential of cloud computing is realized only

when the adopting firm restructures its business model and the organization structures to take advantage of the cloud's capabilities (Brynjolfsson *et al.*, 2010). Business models are also helpful in innovation since they convert market opportunities into profits while delivering the service or product value through commercialization (Amit and Zott, 2012).

However, the impact of Industry 4.0 on business models is a field that has received little attention (Arnold *et al.*, 2016). A lot of advantages from Industry 4.0 technologies are only fully accessible to SMEs if they innovate their existing business models. Firm's internal knowledge as well as its innovation strategy have been proven to be crucial in terms of determining how the business model innovation (BMI) takes place while implementing Industry 4.0. This is especially true in case of SMEs since they are more focused on process innovations and value creation of their existing resources. But the SMEs that have internal drive and exploratory innovation strategy toward Industry 4.0 add significantly more new features to their current business models (Müller *et al.*, 2018).

The strategies that are connected in search of new ideas and new information are 'exploratory innovation strategies' that deals with non-routine problem solving and experimentation with new business models. In an industrial context, studies have demonstrated that exploitation is achieved by having product-market knowledge, utilizing manufacturing experience, and through technological know-how (Wei *et al.*, 2014).

However, exploratory innovation strategies require top management support combined with new abilities that involve searching, adaptability, diversity, and autonomy in decision-making. While SMEs are capable of gathering and acquiring external knowledge, although to transform this knowledge and exploit it for Industry 4.0 adoption is still not satisfactory. It has been noticed that SMEs have limitations in their financial resources as well as IT specialist availability with regards to Industry 4.0 adaptation. The challenges related to resource limitations, low bargaining power are the concerns that the exiting business models are not suitable to apply Industry 4.0 (Müller *et al.*, 2018). A digital leadership can however become a centre of a transformation process with the help of digital technology knowledge and vision enabled with culture, drive, and competence.

It is to be noted that the core of digital transformation is business model innovation (BMI), which can be achieved by using customer experience, digital innovation techniques and ecosystem development. An innovation ecosystem consists of a group of local entities and dynamic processes, which combine together to make solutions for different challenges" (Oksanen and Hautamäki, 2014). Most of the current studies agrees on central aspects while describing business models, that is creating and capturing value by providing a value proposition to customers (Casadesus-Masanell and Ricart, 2010; Zott *et al.*, 2011).

However, it's not just about the consumer in the digital era, but also about the development of the ecosystem in the transformation path (Kane *et al.*, 2017; Valdez-de-leon, 2016). While the traditional enterprises follow known business models and concentrate on optimization and process efficiency, start-ups are looking for a feasible value proposition and a scalable, sustainable business model (Mercandetti *et al.*, 2017).

Start-ups are the firms that invest in innovative products and business models at their initial stage and usually operate in uncertain market conditions. This can also be considered as experimentation stage where new entrepreneurs look for a product or service with a high potential for profit. However, the criteria for larger companies that are intending to digitize their business is changing, since they want start-up firms to promote their digital transformation (Rondani, 2017). A firm's technical ability is crucial in such situation for promoting and supporting a firm's innovation strategy and to sustain success gained from innovation activities (De Franco *et al.,* 2017).

Whereas the management ability can provide an entrepreneur a direction for development of enterprise. However, it is considered that SMEs do not operate in an organized way precisely, in such a case to have results based on a firm's capabilities becomes narrow. Technology innovation competency is therefore critical and can result in a continuous development of the firm if it is being promoted and supported by technological innovations. BMI has become a surviving factor for competition, and it is especially true in the case of SMEs.

However, the innovation potential of SMEs significantly depends up on the resources available in the environment rather than exploitation of their own resources. The SMEs size and age are also a big factor for showing the tendency to cooperate with other entities in the environment. Mostly the large companies rely on their own (internal) resources, while SMEs tend to acquire the necessary resources from the environment. The firms with greater resources have more innovation potential and are more open to their environment (also referred as openness).

For example, the innovation potential and innovation capacity of SME can be denoted by the sum of the resources available inside the firm such as financial, human, knowledge etc. and the external resources which are accessible to the enterprise. Hence the concept of 'open innovation' particularly suits to SMEs. However, previous research confirms that BMI contributes to successful globalization, competitive advantage, and success of SMEs (Asemokha *et al.,* 2019). Moreover, SMEs that participate in BMI can internationalize themselves faster when compared to nonparticipating SMEs (Asemokha *et al.,* 2019).

While Industry 4.0 provides opportunity to increase transaction efficiency at the same time it offers chances to develop novel business model designs (Frank *et al.,* 2019; Müller *et al.,* 2018). An open innovative framework is also important to integrate the collaborative manufacturing models. However, business model innovation is a part of digital transformation, accomplished by rearranging business activities with greater value than the previous ones by optimizing new digital technology (Berman, 2012; Prem, 2015).

4. Findings and Conclusions

SMEs contribute more than half of Europe's gross value added, but they struggle with both Industry 4.0 and business model innovations (BMI), resulting in a lack of external knowledge and uncertain innovation strategies, which limits those company's efforts to

make incremental improvements (Frank *et al.,* 2019; Kotlar *et al.,* 2020; Müller *et al.,* 2018). The most important quality required for innovating a firm is the ability to anticipate market's changing requirements and customer's needs (Trzcielinski, 2021). Access to technology skilled employees with creative mindset is important for product and process innovations while the role of a manager becomes crucial and more relevant factor for developing business model innovations. The connection between digital leadership and innovation in disruptive era shows that digital leadership had influence on innovation (Kreutzer *et al.,* 2017; Wasono and Furinto, 2018) including developing innovative business models.

However, the digital leader should always adopt new ways in doing business, act in a global mind set to interconnect, be more creative to support the innovation culture and must have profound knowledge in risk taking and in making decisions. It has been observed that implementation barriers related to Industry 4.0 implementation are significantly higher in SMEs than compared to larger enterprises due to various reasons including its high costs of investment, SMEs need to pursue innovations in value creation, offer, and capture.

Although small businesses are flexible and can adopt to technological changes very quickly, they simply need to be encouraged by external support such as big companies can share expertise about technology know how's, network partners can effectively share knowledge and resources while financial support must be offered by big organizations for a successful business transformation.

References:

Amit, R., Zott, C. 2010. Business model innovation: Creating value in times of change.

Amit, R., Zott, C. 2012. Creating value through business model innovation. MIT Sloan Management Review, 53(3), 41-49.

Arnold, C., Kiel, D., Voigt, K. 2016. How the Industrial Internet of Things Changes Business Models in Different Manufacturing Industries. International Journal of Innovation Management, 20(8), 1-25.

Asemokha, A., Musona, J., Torkkeli, L., Saarenketo, S. 2019. Business model innovation and entrepreneurial orientation relationships in SMEs: Implications for international performance. J. Int. Entrep., 17, 425-453.

Asian, S. 2019. On the importance of service performance and customer satisfaction in third-party logistics selection. Benchmarking: An International Journal, 26(5), 1550-1564.

Berman, S.J. 2012. Digital transformation: Opportunities to create new business models. Strategy and Leadership, 40(2), 16-24.

Brettel, M., Friederichsen, N., Keller, M. 2014. How virtualization, decentralization and network building change the manufacturing landscape: an industry 4.0 perspective Int. J. Mech. Ind. Sci. Eng., 8(1), 37-44.

Brynjolfsson E., Hoffman, P., Jordan, J. 2010. Cloud computing and electricity: beyond the utility model. Communications of the ACM, 53, 5.

Bughin, J., Kretschmer, T., Zeebroeck, N.V. 2019. Experimentation, learning and stress: The role of digital technologies in strategy change. iCite Working Paper 31.

Buhalis, D., Sinarta, Y. 2019. Real-time co-creation and nowness service: Lessons from tourism and hospitality. Journal of Travel & Tourism Marketing, 36(5) 563-582. 10.1080/ 10548408.2019.1592059.

Burmeister, C., Lüttgens, D., Piller, F.T. 2016. Business Model Innovation for Industry 4.0: Why the Industrial Internet Mandates a New Perspective on Innovation. Die Unternehmnung, 70(2), 124-152.

Büyüközkan, G., Göçer, F. 2018. Digital Supply Chain: Literature Review and a Proposed Framework for Future Research. Computers in Industry 97, 157-177. doi:10.1016/j.compind. 2018.02.010.

Casadesus-Masanell, R., Ricart, J.E. 2010. Competitiveness: business model reconfiguration for innovation and internationalization. Management Research: The Journal of the Iberoamerican Academy of Management, 35(6), 123-149.

Chesbrough, H. 2010. Business model innovation: Opportunities and barriers. Long Range Plan. 43, 354-363.

Chiarello, F., Trivelli, L., Bonaccorsi, A., Fantoni, G. 2018. Extracting and mapping industry 4.0 technologies using wikipedia. Computers in Industry, 100, 244-257.

Costa, P., Porto, G. 2014. Análise da trajetória e da maturidade da cooperabilidade: um estudo com as multinacionais brasileiras Petrobras, Braskem e Oxiteno. RAI – Revista de Administração e Inovação, 11(4), 58-87.

Dalenogare, L.S., Benitez, G.B., Ayala, N.F., Frank A.G. 2018. The expected contribution of Industry 4.0 technologies for industrial performance. Int. J. Prod. Econ., 204, 383-394,

Dallasega, P., Rauch, E., Linder, C. 2018. Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review. Comput. Ind., 99, 205-225. https://doi.org/ 10.1016/ j.compind.2018.03.039.

Dani, S. 2010. Managing risk in virtual enterprise networks: a supply chain innovation perspective. In: Managing Risk in Virtual Enterprise Networks: Implementing Supply Chain Principles, National Technical University of Athens, Greece, 72-91.

De Franco, G., Hope, O.K., Lu, H. 2017. Managerial ability and bank-loan pricing. J. Bus. Financ. Account., 44, 1315-1337.

De Sousa Jabbour, A.B.L., Jabbour, C.J.C., Foropon, C., Godinho Filho, M. 2018. When titans meet–Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors Technol. Forecast. Soc. Change, 132, 18-25.

Eloranta, V., Turunen, T. 2016. Platforms in service-driven manufacturing: leveraging complexity by connecting, sharing, and integrating. Ind. Market. Management, 55, 178-186. https://doi.org/10.1016/j.indmarman.2015.10.003.

Enkel, E., Mezger, F. 2013. Imitation processes and their application for business model innovation: an explorative study. Int. J. Innov. Management, 17(1), 1340005-1-1340005-34.

Foss, N.J., Saebi, T. 2017. Fifteen years of research on business model innovation: how far have we come, and where should we go? J. Management, 43(1), 200-227.

Frank, A.G., Delenogare, L.S., Ayala, N.F. 2019. Industry 4.0 technologies: implementation patterns in manufacturing companies. Int. J. Prod. Economics, 210, 15-26.

Frank, A.G., Mendes, G.H., Ayala, Ghezzi, N.F. 2019. A. Servitization and industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective Technological Forecasting and Social Change.

Geiger, R., Sá, C. 2013. Tapping the Riches of Science: Universities and the Promise of Economic Growth. Cambridge, MA: Harvard.

Ghobakhloo, M. 2018. The future of manufacturing industry: A strategic roadmap toward Industry 4.0. Journal of Manufacturing Technology Management, 29(6), 910-936.

Imran, M., Aziz, A., Hamid, S., Shabbir, M., Salman, R., Jian, Z. 2018. Retracted: The mediating role of total quality management between entrepreneurial orientation and SMEs export performance. Management Sci. Lett., 8, 519-532.

Imran, M., Hameed, W., Haque, A. U. 2018. Influence of industry 4.0 on the production and service sectors in Pakistan: Evidence from textile and logistics industries. Social Sciences, 7(12), 246.

Jovovic, R., Draskovic, M., Delibasic, M., Jovovic, M. 2017. The concept of sustainable regional development–Institutional aspects, policies, and prospects. J. Int. Stud., 10, 255-266.

Kane, G.C., Palmer, D., Nguyen-Phillips, A., Kiron, D., Buckley, N. 2017. Achieving digital maturity. MIT Sloan Management Review, 59(1).

Kotlar, J., De Massis, V., Frattini, F., Kammerlander N. 2020. Motivation gaps and implementation traps: The paradoxical and time-varying effects of family ownership on firm absorptive capacity. Journal of Product Innovation Management, 37(1), 2-25.

Kreutzer, R.T., Neugebauer, T., Pattloch, A. 2017. Digital Business Leadership. Digital Transformation – Geschäftsmodell-Innovation – agile Organisation – Change-Management.

Lasi, H., Fettke, P., Kemper, H.G., Feld, T., Hoffmann, M. 2014. Industry 4.0. Business & Information Systems Engineering, 6(4), 239-242.

Lee, J., Bagheri, B., Kao H.A. 2015. A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manuf. Lett., 3, 18-23.

Liao, Y., Deschamps, F., Loures, E.D.F.R., Ramos, L.F.P. 2017. Past, present, and future of Industry 4.0-a systematic literature review and research agenda proposal. International journal of production research, 55(12), 3609-3629.

Lin, C., Chiu, H., Cho, P. 2006. Agility index in the supply chain. International Journal of Production Economics, 100(2), 285-299.

Lindgren, P., Abdullah, M.A. 2013. Conceptualizing Strategic Business Model Innovation Leadership for Business Survival and Business Model Innovation Excellence. Journal of Multi Business Model Innovation and Technology, 1(2), 113-131.

Lombardi, R. 2019. Knowledge Transfer and Organizational Performance and Business Process: Past, Present and Future Research. Business Process Management Journal, 25, 2-9.

Masaharu Tsujimoto, Yuya Kajikawa, Junichi Tomita, Yoichi Matsumoto. 2018. A review of the ecosystem concept – towards coherent ecosystem design Technol. Forecast. Soc. Chang., 136, 49-58. 10.1016/j.techfore.2017.06.032.

Massa, L., Tucci, C.L. 2014. Business Model Innovation. In: Oxford Handbooks Online 1-25.

Mercandetti, F., Larbig, C., Tuozzo, V., Steiner, T. 2017. Innovation by Collaboration Between Startups and SMEs in Switzerland. Technology Innovation Management Review, 7(12), 23-31.

Mittal, S., Khan, M.A., Romero, D., Wuest, T. 2018. A Critical Review of Smart Manufacturing & Industry 4.0 Maturity Models: Implications for Small and Medium-Sized Enterprises (SMEs). Journal of Manufacturing Systems, 49, 194-214.

Müller, J.M., Buliga, O., Voigt, K.I. 2018. Fortune favours the prepared: how SMEs approach business model innovations in Industry 4.0. Technological Forecasting and Social Change, 132, 2-17.

Müller, J.M., Kiel, D., Voigt, K.I. 2018. What drives the implementation of Industry 4.0? the role of opportunities and challenges in the context of sustainability. Sustainability, 10(1), 247, 1-24.

Nawanir, G. 2016. The effect of lean manufacturing on operations performance and business performance in manufacturing companies in Indonesia, Ph.D., Thesis, Universiti Utara Malaysia.

Oksanen, K., Hautamäki, A. 2014. Transforming regions into innovation ecosystems: A model for renewing local industrial structures. Innov. J. Public Sect. Innov. J., 19, 1-16.

Osterrieder, P., Budde, L., Friedli, T. 2019. The smart factory as a key construct of industry 4.0: A systematic literature review. Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2019.08.011.

Pavlović, M., Radosavljević, M., Milojević, R. 2018. The role of information technology in the implementation of lean concept. Facta Universitatis. Series: Economics and Organization, 15(4), 349-362. https://doi.org/10.22190/FUEO1804349P.

Prem, E. 2015. A digital transformation business model for innovation. The Proceedings of the 2015 ISPIM Innovation Summit in Brisbane. Australia 6-9 December.

Ramsauer, C. 2013. Industrie 4.0 – die produktion der Zukunft. WING Bus., 3, 6-12.

Reischauer, G. 2018. Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. Technol. Forecast. Soc. Change, 132, 26-33.

Rondani, B. 2017. Contratos entre Grandes Empresas e Startups Crescem 194% no Brasil. Revista PEGN – Pequenas Empresas Grandes Negócios.

Rong, K., Hu, G., Lin, Y., Shi, Y., Guo, L. 2015. Understanding business ecosystem using a 6C framework in Internet-of-Things-based sectors. International Journal of Production Economics, 159, 41-55.

Rübmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnisch, M. 2015. Industry 4.0: The future of productivity and growth in manufacturing industries. Boston Consulting Group.

Sabri, Y., Micheli, G.J.L., Nuur, C. 2018. Exploring the Impact of Innovation Implementation on Supply Chain Configuration. Journal of Engineering and Technology Management, 49, 60-75.

Saebi, T., Lien, L., Foss, N.J. 2016. What drives business model adaptation? The impact of opportunities, threats, and strategic orientation. Long Range Planning, 50(5), 567-581.

Shahbaz, M.S., Soomro, M.A., Bhatti, N.U.K., Soomro, Z., Jamali, M.Z. 2019. The impact of supply chain capabilities on logistic efficiency for the construction projects. Civil Engineering Journal, 5(6), 1249-1256, 2019.

Sommer, L. 2015. Industrial Revolution-Industry 4.0: Are German Manufacturing SMEs the First Victims of This Revolution? Journal of Industrial Engineering and Management, 8(5), 1512-1532. doi:10.3926/ jiem.1470.

Teece, D. 2007. Explicating Dynamic Capabilities: The Nature and Micro foundations of (Sustainable) Enterprise Performance. Strategic Management Journal, 28(13), 1319-1350. DOI: 10.1002/smj.640.

Trappey, A.J.C., Trappey, C.V., Govindarajan, U.H., Sun, J.J., Chuang A.C. 2016. A review of technology standards and patent portfolios for enabling cyber-physical systems in advanced manufacturing Adv. Eng. Inf., 4.

Trzcielińska, J., Kaps, R. 2021. Business Models and Opportunities Recognition, 37th IBIMA Conference: 30-31 May, Cordoba, Spain.

Trzcielinski, S. 2021. The Impact of Changes Perceived in the Environment on the Agility of the Enterprise. Eds: S. Trzcielinski, B. Mrugalska, W. Karwowski, E. Rossi, M. Nicolantonio. Advances in Manufacturing, Production Management and Process Control. Proceedings of the AHFE 2021 Conferences on Human Aspects of Advanced Manufacturing, Advanced Production Management and Process Control, and Additive Manufacturing, Modeling Systems and 3D Prototyping. Cham, Springer, 419-427.

Valdez-de-Leon, O. 2016. A digital maturity model for telecommunications service providers. Technology Innovation Management Review, 6(8).

Wagner, S.M., Sutter, R. 2012. A qualitative investigation of innovation between third-party logistics providers and customers, Intnl Jour of Prod. Econ., 140(2), 944-958.

Wang, S., Wan, J., Zhang, D., Li, D., Zhang, C. 2016. Towards smart factory for industry 4.0: a self-organized multi-agent system with big data-based feedback and coordination. Comput. Network., 101, 158-168.

Wasono, L.W., Furinto, A. 2018. The effect of digital leadership and innovation management for incumbent telecommunication company in the digital disruptive era. International Journal of Engineering and Technology, 7, 125-130.

Wei, Z., Song, X., Wang, D. 2017. Manufacturing flexibility, business model design, and firm performance. Int. J. Prod. Econ., 193(28), 87-97.

Wei, Z., Zhao, J., Zhang, C. 2014. Organizational ambidexterity, market orientation, and firm performance. Journal of Engineering and Technology Management, 33, 134-153.

Wischmann, S., Wangler, L., Botthof, A. 2015. Industrie 4.0: Volks- und Betriebswirtschaftliche Faktoren für den Standort Deutschland. B.f.W.u.E. (BMWi) (ed.). Berlin: BMWi.

Xu, L.D., Xu, E.L., Li, L. 2018. Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941-2962.

Yang, C.C. 2012. Assessing the moderating effect of innovation capability on the relationship between logistics service capability and firm performance for ocean freight forwarders. A Leading Journal of Supply Chain Management, 15(1), 53-69.

Yunus, M., Moingeon, B., Lehmann-Ortega, L. 2010. Building social business models: Lessons from the Grameen experience. Long Range Planning, 43(2-3), 308-325.

Zott, C., Amit, R. 2017. Business Model Innovation: How to Create Value in a Digital World. GfK Marketing Intelligence Review, 9(1), 18-23.

Zott, C., Amit, R., Massa M. 2011. The business model: recent developments and future research. Journal of Management, 37, 1019-1042.