ASECU South-Eastern Europe Journal of Economics 1 (2023) 81-92 SEEJE

SUSTAINABILITY AND INNOVATION: THE CASE OF INDUSTRY 4.0

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Abstract
In the last years, sustainability is increasing in popularity not only among firms but also among their stakeholders. In addition to a growth in sales, companies can improve their financial and investment opportunities as well as reduce operational costs and become more productive, minimize carbon fossil used and improve energy efficiency, opting for renewable opportunities, such as solar energy and wind power. According to the literature, there seems to be a correlation between sustainable companies and innovation. Therefore, advanced technologies may contribute to sustainability. This is the case of the Fourth Industrial revolution, an industry paradigm shift introducing many new technologies. Thanks to such technologies, it is indeed possible to monitor and reduce emissions, diminish waste and have a more efficient production. Research suggests that there are differences as larger firms are more technologically advanced and more innovative than smaller ones. Assuming that technological level is an indicator of sustainable practices, the objective of this paper was to assess differences at technological level among micro, small, medium and large companies. This was achieved by analyzing data of a survey conducted in Slovakia and Italy, the respondents to which were owners and managers.

Keywords: Sustainability, Industry 4.0, Digitalization.

JEL Classification: O30, O33, Q56

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1. Introduction

Policy makers, consumers and other stakeholders – including many employees enthusiastic about greener production - are now demanding products made using sustainable practices. This is due to an increasing awareness of the importance of fighting climate change and being more environmentally friendly. Consumers are then likely to reward companies compliant with these principles by purchasing from and being loyal to them even if their products are more expensive. Similarly, investors may decide to invest in sustainable companies as they are more appealing from a financial perspective; in other words, sustainability increases a firm's value. Moreover, all economic activity is dependent on and conditioned by both renewable and non-renewable natural resources (Rout, Verma, Bhunia, Surampalli, Zhang, Tyagi, Brar & Goyal, 2020). Therefore, their wise consumption and use in production are a must.

The perception of a global environmental crisis initially appeared in governments' agendas in the middle of the 20th century, but it was only in 1987 that the World Commission on Environment and Development (WCED) was formed (Lazaretti, Giotto, Sehnem & Bencke, 2019). As a result, certain practices that were performed by firms in the last century are now done differently and no longer accepted because they harm the environment. Indeed, in the past, there was no or little concern regarding sustainable practices and in respect to the damage firms might inflict to the environment. Technology development can enhance sustainable practices by ensuring improved efficiency and using resources better. Nevertheless, it often occurs that the availability of these technologies has the opposite outcome: increased pollution and resource overuse (Rout et al., 2020).

Hopefully, thanks to very advanced technologies, firms can be sustainable in their everyday routines. The paradigm shift towards Industry 4.0 (I4.0) (the Fourth industrial revolution) makes sustainability possible and is characterized by such technologies, which offer efficient solutions for energy savings, control of emissions and machinery maintenance (Garetti & Taisch, 2012). Nonetheless, I4.0 does not necessarily mean inevitable sustainability: sustainability and I4.0 should be considered jointly, i.e. the former should be "the very core of the Industry 4.0 strategy" (Piccarozzi, Aquilani & Gatti, 2018, p. 19). What is more, sustainability is a central issue when planning innovation and formulating new strategies (Adams, Jeanrenaud, Bessant, Denyer & Overy, 2016). In the agricultural sector, the paradigm shift is known as Agriculture 4.0, and it improves traditional farming practices that allow farms to ensure sustainability of agricultural and agrifood production processes as well as transparency of their operations (Spanaki, Karafili & Despoudi, 2021). In addition to agriculture, I4.0 can be adapted to every sector, industries, and companies regardless of their size.

The objective of this paper was to assess the technological level of companies of different sizes, specifically micro, small, medium, and large companies. The rest of the article is organized as follows: First, there is a literature review conducted on

sustainability and the ways in which I4.0 can support and enhance it; then the methodology used to analyze the questionnaire is presented and the last part presents a discussion based on our results.

1.1 Sustainability and Industry 4.0: a literature review

In this section, sustainability and I4.0, as well as the role of the latter in enhancing green practices in meeting the principles of sustainable development, are examined.

Sustainability is a wide concept that stresses the importance to preserve resources so that future generations can also make use of them. Indeed, sustainable development recognizes the interdependence of environmental, i.e. the impact of natural resources and pollutant emissions, social impacts of innovations on communities within which the organization carries out its business, and efficient economic systems (Khan, 2016). Such balanced integrated policies concerning society, the environment, and economy are to the advantage of current and future generations (Geissdoerfer, Savaget, Bocken & Hultink, 2017). Since the 1970s, the three have been jointly referred to as the pillars of sustainability, although some papers also include other aspects, such as institutional, cultural, and technical (Purvis, Mao & Robinson, 2019). However, it is possible to argue that these additional dimensions are already included in the three pillars. Another name to refer to them is, among others, three bottom pillars (TBP). Externalities of socio-environmental and economic parameters affect the pillars (El Baz, Tiwari, Akenroye, Cherrafi & Derrouiche, 2022).

A more specific concept of sustainability for firms is business sustainability. This is the ability to generate resources so as to compensate production factors (i.e. inputs), to replace used assets, and to invest and maintain competitiveness (Barbieri, Vasconcelos, Andreassi & Vasconcelos, 2010 cited in Kuzma, Padilha, Sehnem, Julkovski & Roman, 2020), the aim being to positively affect society as a whole (note that the basic pillars are included in this definition, too). Moreover, today's sustainable businesses must effectively fulfil social, financial, and profitability objectives and this can significantly contribute to financial and environmental problems (Javaid, Haleem, Singh, Suman & Gonzalez, 2022). The environmental and social dimensions of sustainability should be considered of equal importance to economic ones, i.e. the pillar most studied (Piccarozzi, Silvestri, Aquilan & Silvestri, 2022) – namely profitability in business and market share – when formulating strategies (Kuzma et al., 2020). This is the only way firms can aspire to be really sustainable since all the three pillars are valued and balanced.

Even the choice of suppliers is relevant if a firm seeks true sustainability. Apple and Dell had suppliers whose employees had to work in dangerous conditions to produce the electronic parts; Nike and Adidas' suppliers were dumping toxins into rivers in China. In order to avoid these undesirable behaviors, firms have to establish long-term sustainability goals and demand first-tier (the closest to the firm) suppliers to set their own long-term sustainability goals; the overall sustainability strategy

should include lower-tier suppliers, too (Villena & Gioia, 2020). There are diverse tools to perform supplier sustainability assessments (Lee & Kashmanian, 2013 cited in Matthess, Kunkel, Xue & Beier, 2022).

According to the literature, there seems to be a correlation between innovating firms and sustainability. Nidumolu, Prahalad and Rangaswami (2009) argue that innovation is a great supporter of sustainable development and provides a competitive advantage (cited in Lazaretti et al., 2019). From the literature review by Piccarozzi et al. (2022), it is generally possible to find a positive relation, not always precisely quantifiable, that emphasizes "a positive potential impact of innovations on sustainability dynamics". Thanks to innovation, companies can advance their processes and improve their products by using more eco-friendly materials, being more efficient in their production and reducing their waste.

I4.0 represents a group of innovations that not only increase companies' efficiency, reduce costs, can beat "traditional" companies, while they can comply with the other two pillars of sustainability and maintaining high quality standards. It positively affects socio-environmental and economic externalities (El Baz et al., 2022). For instance, if, on the one hand, many job positions are disappearing, new job opportunities are being created. Advanced technologies can enhance safety and working conditions: risky and repetitive tasks are already performed by machines. According to various authors, social welfare can be improved, too. This is due to a promising growth of minimum wages due to "skill intensiveness" (El Baz et al., 2022) that would reduce economic inequality through increased global accessibility of goods and services and their affordability for production cost reduction while satisfying the demands of individual customers by offering personalized solutions (customization of goods).

These technologies and the blurring of reality and the virtual world are the true essence of I4.0. Digital automation of sustainable energy processes is among the essential factors that can by enhanced by Industry 4.0 technologies. Note that some technologies have an indirect effect on sustainability (e.g. augmented reality) (Chiarini, 2021 cited in Piccarozzi et al., 2022). Regardless of whether the influence is direct or indirect, enabling technologies pursuing the economic and environmental pillars of sustainability are Autonomous Robots, Additive Manufacturing, Cloud Computing, Autonomous Robots, Cybersecurity and Augmented Reality (Ramirez-Peña, Sánchez Sotano, Pérez-Fernandez & Batista, 2020). Other technologies that should be integrated and can contribute to the social principle of sustainability are Big Data, Blockchain, Simulation, Internet of Things and Artificial Intelligence (Piccarozzi et al., 2022). Furthermore, digital technologies offer various opportunities to improve both data availability and verifiability of supply chains sustainability claims. I4.0 enables data collection of sustainability-related data at different stages in the supply chain (carbon emissions in logistics and recyclability or reusability of discarded

products), thanks to, e.g. radio-frequency identification (RFID) (Rane & Thakker, 2019 cited in Mattheus et al., 2022).

The next section summarizes the essential challenges firms face when performing and successfully upgrading their technologies or innovating, in general.

1.2 Implementing technologies of Industry 4.0

Digitalization of companies is not always smooth since firms often have to deal with challenges and barriers, which range from those of a financial and operational nature, to those related to human beings and to strategic aspects (Marcon, Marcon, Le Dain, Ayala, Frank & Matthieu, 2019). A wide range of barriers and the importance given to them can change in various sectors/industries. Moreover, the literature has highlighted issues companies encounter in accepting and developing new technology (Lee & Xia, 2006; Rogers & Networks, 2004; Shefer & Frenkel, 2005; cited in Na, Heo, Choi, Han & Kim, 2023). Quite an obvious factor is the diverse availability of resources. As the size of companies increases, financial opportunities rises, too. Financial constraints may be a big problem for smaller companies due to their difficulties in purchasing the latest available technologies, which, in turn, would increase the gap between bigger and smaller firms. Other determinants are the maturity level of technology, which does not reach an acceptable or unified level for small and medium enterprises (SMEs), the perceived complexity of new complexity and the necessary skills and competences in using new technologies (Prause, 2019; Rogers, 1995). These would be usually uncommon in larger companies, where more specialized positions may be found. Conversely, smaller companies have the advantage of being more flexible and adaptable than larger ones (Na, Heo, Choi, Han & Kim, 2023).

Furthermore, training in using these technologies is better done in bigger companies, whereby more resources (time and money) are available and can be allocated to it. Training is different with respect to technological and financial opportunities available to firms of different sizes and industries (Boothby, Dufour & Tang, 2010). Generally speaking, big companies and small ones do not have equal opportunities in Industry 4.0 (Horváth & Szabó, 2019). Indeed, big companies have higher driving forces and lower barriers than small and medium enterprises.

In addition to the human resources barriers of necessary training to acquire competences for effectively using novel technologies, there are relevant psychological ones, too. Among them, resistance to change is quite significant and may be rooted in organizational culture. Several studies (e.g. Hansen, 1992, Jaumandreu, 2004; cited in in Lousã & Gomez, 2017) found that there is a negative relation between company size and innovation support culture (e.g., Chandler, Kellerand & Lyon, 2000; Rebelo & Gomes, 2011 cited in Lousã & Gomez, 2017). Similarly, a company's age seems to be negatively related to innovation.

2. Data and Methods

The aim of this article was to assess differences among micro, small, medium and large companies concerning their technological level. Hence, this study tested previous studies' outcomes. As such, a closed-ended questionnaire was sent by email to Slovak- and Italy-based companies. Respondents were mainly company owners and managers. The article comprises three sections, the first 2 of which were needed for the current paper's objective (Table 1), i.e. Likert scale questions to measure the technological level and classification to identify the cohort of companies according to size. It was assumed that firms of a higher technological level (i.e. more I4.0 novelties) are more sustainable than traditional ones. It was expected that bigger firms would present a higher degree of advanced technologies than smaller firms due to greater amounts of (financial) resources. More formally, based on previous studies:

H1. In the I4.0 context, there is a significant difference regarding technological levels among companies of different sizes.

To test hypothesis H1, i.e. to statistically analyze the differences of one category from another, the non-parametric Kruskal-Wallis test, was chosen, since the data were ordinal (and, therefore, not normally distributed). This test is used for the analysis of differences in cases of more than two groups (for example, company size comprising 4 groups: micro, small, medium and large firms). Because the test does not say much about where the differences lie, Bonferroni post-hoc test was used every time the Kruskal-Wallis was significant. Analyzing the Likert-like scale questions, ranging from 1 to 7 (1 = total disagreement and 7 = total agreement with a statement), it is possible to see the actual use of the specific technology. Thus, every time the mean of each question was greater than 3.5 (mean value), the particular technology was assumed to be not only installed but also regularly used by the companies of each category.

Table 1: Section of the questionnaire

Type of questions	n° questions	Examples
Sample characteristics	12 Q.	e.g. *work position, years employed, location, industry, and size of company*
Likert-like scale	28 Q.	About *personal, marketing and customer, strategic and technological innovation*
Ranking	04 Q.	About barriers to I4.0 *of strategic, organizational* and *human nature*

Source: author's elaboration based on own questionnaire.

The sample totaled 102 answers (62 from Italy and 40 from Slovakia). The entities operated in many different industries and sectors – more than 30 - grouped into two major types: manufacturing (or product) and service industries. Service industries are usually dealing with customers (final user or B2B) without manufacturing any product but delivering it. Firms belonging to product industries have to do with tangible products instead: for example, car, furniture, and heavy machinery manufacturing. In the product group (63 companies), the main companies were mechanical and electrical engineering (13) ones, followed by commercial (5) and agricultural firms (4). In the service group, more than half companies provided financial and professional services (23 over 37). Note that 2 answers were removed as not classifiable. Among the companies surveyed and compared to 2020, 37 enjoyed a better economic status, while this remained unchanged for 31 of them; finally, 34 experienced a worsening of their status. In 38 of firms, foreign investors contributed to the capital structure and just 4 companies were owned publicly or by the State. Taking into consideration the size of companies, the sample comprises: 26 micro (≤ 10 employees); 22 small (10-49 employees); 26 midsized (50-249 employees); and 28 large companies (≥250 employees).

Work positions of respondents were grouped under 4 labels: lower managers (28), top managers (28), owners (22) and others (grouping other positions, 24). Qualification titles started from pre-university titles to post-graduated education. Respondents in possession of a post-graduate title (included PhD) were 65% of the sample. Lastly, 58% of respondents had been employed in their companies for more than 5 years.

3. Results and Discussion

Mean values for each category are reported in Table 2 (see Appendix for corresponding questions). Mean values lower or equal to 3.5 are highlighted in red. Note that as the number of employees increases (and so does the size of the firm), the score for each question related to technology becomes greater. Overall, with the exception of micro firms, all companies of the sample have adopted and used the latest technologies. Moving to technologies, it looks as if Augmented Reality and Virtual Reality technologies are not so popular among the firms studied (average score is never greater than 3.5). Interestingly, end-to-end supply chain (Q4) is fairly common among all companies, even among micro ones.

Table 2: results of the questionnaire

Firms	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
Micro	3.88	3.35	2.85	3.54	2.23	4.50
Small	4.86	4.00	3.23	4.00	2.41	5.73
Midsized	5.65	5.31	4.31	4.50	3.08	5.42
Large	5.54	5.36	4.54	5.18	3.50	5.86
Average for the sample	*5.00*	*4.54*	*3.76*	*4.33*	*2.83*	*5.37*
Sig. Kruskal-Wallis test	*.005*	*.000*	*.002*	*.009*	*.019*	*.025*

Source: Author's own calculation based on the questionnaire

Due to this lower score and the significant difference, compared to other firms, micro-companies were investigated further. More specifically, the industries and sectors in which each micro firm operates were studied in more detail. Most of them are involved in the financial sector. Surprisingly, most of them do not make use of Big Data, and do not have a digital vision. This would be expected from firms making bakery products, which score 1, on average, similarly to commercial companies (mean = 1). Agriculture-related firms (including farms) never scored higher than 3. The Kruskal-Wallis test confirms that there are statistical differences among groups. Therefore, the hypothesis (**H1**) should not be rejected. Further investigation to identify the differences was performed using a Bonferroni post-hoc test: for all technologies, micro firms and large companies present statistically different results. More specifically, for Q1 (digital vision), Q2 (Big Data usage) and Q3 (Artificial Intelligence), there are differences between micro and midsized firms, too. Lastly, small and large firms vary regarding their usage of big data.

The reason why these differences occur might be due to the greater financial possibilities of large companies and the sector in which these do their business. Investments are indeed key for the 4IR since, without them, the digitalization process cannot be performed. Taking advantage of I4.0 is challenging, particularly for SMEs, as this requires significant investments in technologies (Vaidya, Ambad & Bhosle, 2018; Agostini & Nosella, 2019). Moreover, when the survey was submitted, I4.0 technologies' maturity level would have been perceived as not satisfactory.

Besides these findings, related questions were about smart-working, popular after the spread of the COVID-19 pandemic. According to the respondents of firms that allowed for smart working, the pandemic experience accelerated the process towards a 'smart' company (mean = 5.55), i.e. their companies speeded up the adoption of technologies 4.0.

4. Conclusion

This paper tested the statistical difference between companies of diverse sizes. Based on the literature, it was assumed that there is a link between sustainability and I4.0, i.e. the more technologically advanced a company the more sustainable it is (beyond the scope of this paper). Being sustainable is crucial nowadays so that resources can be preserved for future generations and improve conditions for current human generations. Latest technologies of the industry shift to I4.0 can positively affect the three pillars of sustainability by providing technologies that increase safety and improve employees' working conditions, new job positions, energy savings and CO_2 emission control, increased wages and improved availability and affordability.

Implementing I4.0 in companies presents several challenges and obstacles to be surmounted, as identified in some studies in relevant literature (e.g. Marcon et al., 2019). Challenges and obstacles are of different natures, varying from operational and strategical to those of human resources. More specifically, they are related to resistance to change, financial opportunities and time to dedicate to training. The questionnaire confirmed the results of previous studies: as the size of companies increases, organizations present a higher degree of advanced technology. This may be due to various reasons, such as more investment opportunities for larger companies, propensity to risk since smaller firms tend to prefer mature technologies (again, money may be the reason) and availability of competences in using these new technologies. Moreover, micro firms appear to be so different compared to other firms scoring significantly lower than them to questions related to the technologies 4.0 they have and use.

Perhaps funds and incentives provided by the Slovak and Italian governments, as well as the European Union (European Green Deal), will not only make it digital transition easier but also reduce the gap among companies. From a management perspective, digitalization allows improved efficiency in operation and advantages in terms of lower (production) costs, and deepens customers' needs and preferences. This reflects the importance of upgrading technologies to I4.0. Moreover, tailoring strategies for implementation of I4.0 technologies centered on sustainability is also significant. The overall result of the transition will be that firms will be pursuing sustainable practices.

4.1 Limitations and future research

The study has some limitations. The statistics used cannot prove causality or absolute truth to corroborate the hypothesis due to the particular sample and the limited number of companies composing it. The geographic area may bias the results: two developed countries members of the European Union. Additional shortcomings may derive from the nature of close-ended questions as well. Such questions cannot cover all possible options (e.g. all technologies) and they are limited to providing details

about a specific topic and possible misinterpretations may not be apparent. Future research may aim at analysing the results in other countries situated in other continents. Besides, new evidence may emerge on the link between technological advancement and sustainability, as well as the factors significantly different between larger and smaller companies.

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Appendix

Questions from the questionnaire:

Q1: Your company has a digital vision clearly stating strategy and culture needed to support digital transformation.

Q2: The use of big data analysis has increased in your company in the last years.

Q3: Artificial Intelligence (AI) is extensively used in your company.

Q4: Supply chain is end-to-end planned in your company.

Q5: Augmented Reality (AR) and Virtual Reality (VR) are used by employees, among other applications, for self-learning and training.

Q6: You believe that in the immediate future new technologies will increase your company's profits.

Q7: Smart working made you and your colleagues deepen/expand your technological knowledge.

Q8: In certain ways, smart working accelerated the process towards a "smart" company.