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A new wave and the ripples it makes: Post-transition firm's digital maturity and its consequences in global value chains

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ABSTRACT

Objective: The objective of the article is to assess the firms' digital maturity and examine how the adoption of Industry 4.0 solutions affects global value chain (GVC) relationships.

Research Design & Methods: The study combined a critical literature review with quantitative empirical research. We collected the primary data during computer-assisted telephone interviews (CATI) among 400 industrial manufacturing firms in Poland.

Findings: The study demonstrates that I4.0 technologies adoption modifies the awareness of partners' progress in digital transformation, affects integration among partners, and leads to changes in GVCs' diversification, geographic scope, and governance. Thanks to the study on the digital maturity of firms from a post-transition country, we demonstrated that I4.0 still requires conceptual development and that the emerging theory of the Fourth Industrial Revolution is interdependent with the theory of GVCs.

Implications & Recommendations: We focused on the disruption caused by the advancement of digital transformation in companies that operate in a constellation of relationships and are interdependent in the same GVC. The study recognizes the relationships within the GVC as channels of transmission of challenges, risks, and opportunities that emerge from the disruption. We referred to the case of a post-transition, post-communist country in Central and Eastern Europe under digital transformation, which is highly specific yet offers valuable findings transferable to other economies on the eve of the Fourth Industrial Revolution.

Contribution & Value Added: The novelty of the study lies in the integration of research on digital technology adoption as diagnosed among manufacturing companies in a post-transition country with the inquiry regarding their participation and role in GVCs. Thanks to this approach, we identified how firms' digital maturity reshapes their buyer-supplier relations and, thus, their position in value chains.

Article type: research article

Keywords: digital maturity; global value chains; post-transition economy; Poland; Industry 4.0

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INTRODUCTION

The literature on Industry 4.0 (I4.0) maturity is growing continuously (Müller *et al.,* 2018; Mittal *et al.*, 2018). Scholars have examined the implications of I4.0-entailed digital transformation for management and organization studies (Appio *et al.*, 2021; Ardito *et al.,* 2019; Correani *et al*., 2020; Usai *et al.,* 2021; Qin *et al.*, 2016). The adoption of I4.0 made the relations and interactions between products, processes, and systems more intricate and dynamic, leading to new challenges (Fareri *et al.,* 2020; Plekhanov *et al.,* 2022). Nevertheless, there is still no consensus regarding the precise definition and assessment of I4.0 maturity.

The main objective of this study is twofold. We will propose how to diagnose the level of digital maturity of firms operating in global value chains (GVCs). Secondly, we will identify the implications of the adoption of I4.0 technologies for firms operating in GVCs. In other words, we will argue that digital ma-

turity goes beyond the metrics that focus just on the I4.0 adoption and can be defined in terms of firms' broader awareness, knowledge, and understanding of partners in digital processes. We used synonymously I4.0 as the Fourth Industrial Revolution and digital business transformation. We will demonstrate that the implementation of I4.0 solutions bears consequences not only for a company but also echoes and reverberates in GVCs, sending ripples that affect cooperating partners. Moreover, we shed light on the adoption of I4.0 technologies by firms from a post-transition or in other words – post-communist country such as Poland. All available reports and statistical databases indicate the persistent laggardness of post-communist countries in the area of innovation or digital transformation with perhaps some sectoral or regional exceptions (PIE Report, 2019; Rostkowski, 2019; Fifekova *et al.*, 2018; Szalavetz, 2020b or see Cséfalvay, 2019 for sectoral differences). Rückert *et al.* (2020) confirmed the emergence of a digitization divide among European companies. Poland is one of the weakest countries in terms of its digital competitiveness among the EU member states (https://ec.europa.eu/digital-single-market/en/desi).

This exploratory study contributes to the research on digital maturity and GVCs as channels of transmission of risk and challenges generated by the Fourth Industrial Revolution (4IR). Studies are presenting how inter-firm relationships impact their innovation performance (Qian *et al*., 2022; Yang *et al*., 2020) but there remains a gap in how I4.0 technologies associated with technological and business innovations affect the cooperation patterns in GVCs (Chen, 2019). The novelty of the study lies in the integration of research on digital technology adoption as diagnosed among manufacturing companies in a post-transition country with the inquiry regarding their participation and role in GVCs. Thanks to this approach, we identified how the digital maturity of firms reshapes their buyer-supplier relations, thus their position in value chains (Kumar & Srivastava, 2020; Sharma *et al*., 2019). This study relied mainly on a critical literature review and primary data collected from November 2019 to January 2020 during computer-assisted telephone interviews (CATI) among 400 firms established in Poland.

Firstly, we will provide background information on I4.0 's premises and technologies. Then, we will refer to the measurement issue of I4.0 maturity and GVCs reorganization facilitated by I4.0 solutions. Next, we will report on the methodological approach applied in their study. This will be followed by the presentation of results based on secondary and primary data and a discussion of findings. The article will close with a general discussion and main conclusions.

LITERATURE REVIEW

Industry 4.0 Maturity

The literature on the 4IR steadily grows in number, including systematic reviews that summarize related definitional and conceptual aspects (Kamble *et al.,* 2018; Szalavetz, 2020; Götz *et al.*, 2018).

The most frequently used technologies in the context of Industry 4.0 's development include big data analysis (BDA), augmented reality (AR), autonomous robots, internet of things (IoT), simulation, horizontal and vertical system integration, cloud, cybersecurity, additive manufacturing (Rüßmann *et al.,* 2015; Mendhurwar & Mishra, 2018; Rymarczyk, 2020; Giza & Wilk, 2021; Gliszczyński & Ciszewska-Mlinarič, 2021; Doanh *et al*., 2023; Sieja & Wach, 2023). Besides these technologies, scholars also mention social media instruments as the manifestation of I4.0. They provide firms with a great amount of information that contributes to the benefits of the adoption of I4.0 technologies (Yang & Gu, 2021). Mobile technologies allow us to reach these social media instruments quickly, easily, and at a low cost. In this context, both social media and mobile technologies belong to the basket of I4.0 solutions.

The advancement of companies' digital transformation manifests itself in the number and diversity of adopted I4.0 technologies, which determines their level of I4.0 maturity. The literature provides more and more studies on the construction of I4.0 maturity indices (Tutak & Brodny, 2022; Pacchini *et al.,* 2019; Mittal *et al*., 2018; Schumacher *et al*., 2016; Demary & Matthes, 2015; Gracel, & Łebkowski, 2018). However, most of the works are conceptual and the proposed indices still need to be tested.

The indices differ in construction but what is characteristic is that they refer to the number and diversity of adopted I4.0 technologies, which determines the level of the firms' I4.0 maturity. Another typical aspect is that indices referring to the micro-level apply the self-assessment of companies and are often based on data collected in interviews with managers (Basl & Doucek, 2019; Gracel & Łebkowski, 2018).

The speed, scale, and scope of digital transformation necessitate far-reaching collaboration between partners, which makes the assessment of the I4.0 maturity even more challenging. The I4.0 's interlinked, integrated, and automated nature implies the need for interoperability and common standards. The question arises of how much particular technologies are known, appreciated, and adopted not only by single entities but how many economic actors are ready or mature enough to create value as interdependent agents. Thus, as argued by Agostini and Nosella (2020) and Sena *et al*. (2019), I4.0 implies a far-reaching transformation not only of individual companies but the whole ecosystems. The latter manifests itself in the growing compatibility among firms, resulting in the emergence of the phenomenon of connected companies and vanishing boundaries of single firms, which reflects the integration among them, accompanied by the need for more interoperability. Firms are no stand-alone units, so when they want to become more digitally mature, they must be aware what is their partners' status of digital maturity and make efforts to integrate with them, learn from them and share knowledge (Lane *et al.*, 2001; Lewis *et al.,* 2008; Medjani, & Barnes, 2021). Thus, we formulated the following research proposal:

Proposition* 1*: The greater the firm 's digital maturity, the higher the firm 's awareness of the progress in the digital transformation of its partners (RP1A) – including suppliers (RP1Aa), clients (RP1Ab), competitors (RP1Ac), and providers of the firm's products' substitutes (RP1Ad) – and the stronger the firm's attempts to integrate cooperating partners (RP1B).

Through the research, we wanted to emphasize the evolution in the approach to Industry 4.0 from a strictly technological attitude through an organizational and managerial approach to a wider horizontal lens involving partners of a given company's ecosystem.

Considering the universal character and transversality of I4.0 technologies, the related disappearance of borders between sectors and the spreading influence of I4.0 technology application in elements of the company's environment, we assumed that from the company's perspective, the introduction of such solutions forces more integration with its partners or even makes it beneficial.

Global Value Chain Reorganization Facilitated by Industry 4.0

Gereffi and Fernandez-Stark (2016) define GVCs as the full range of tangible and intangible activities undertaken by inter-firm networks on a global scale to introduce products or services from conception to end use and beyond. In other words, GVCs encompass firms with their suppliers and buyers.

Recent advances in digital technology promise formidable changes across supply chain activities (Kagermann, 2015), and I4.0 perceived as a business model innovation (Brettel *et al*., 2014) justifies the adoption of a novel approach to study supply chain management (Büyüközkan & Göçer, 2018). To properly identify the implications of I4.0 for GVCs, the specialization, geographic scope, and governance of networked actors must be considered (Gereffi & Fernandez-Stark, 2016), along with upgrading as the key analytical dimensions (Humphrey & Schmitz, 2002; Ponte & Ewert, 2009; Barrientos *et al.*, 2011; Sass & Szalavetz, 2013). As far as the specialization aspect is concerned, the emergence and application of technologies covered by the umbrella term 'Industry 4.0' can reverse the previous trends of offshoring (Laplume *et al*., 2016) and reduce the number of production stages – thus leading to a collapse of GVC lengths (Rezk *et al.*, 2016) – change the geographical location attractiveness of new investments' hosts (Gress & Kalafsky, 2015), and disintegrate previously established linkages (Rehnberg & Ponte, 2018). As argued by Chiarvesio and Romanello (2018), I4.0 may change the logic behind firms' decisions concerning the type or number of activities in value chains that they wish to control. Moreover, I4.0 could affect productivity, which in turn, would impact geographic choices. The combination of the impact of robotization and automatization with two dimensions of GVCs – specialization and geographic scope – may result in GVCs becoming structurally less complex and geographically much shorter (Csefalvay, 2020; De Backer & Flaig, 20172). The type of governance in GVCs may be reorganized thanks to collaboration and competition in the GVCs (Canning & Kelly, 2015). Thus, to capture the broad and multidimensional trends in GVCs, we formulated the following research proposal:

Proposition* 2*: The greater the firms' digital maturity, the greater the changes in the GVC in terms of diversification (RP2a), geographical scope (RP2b), and governance (RP2c).

Thus, referring to the still ambivalent assessments of the impact of I4.0 on the functioning of GVCs, we assumed that such reconfigurations will occur in terms of industry, geography, and functions, hence the above RP2.

RESEARCH METHODOLOGY

We combined a critical literature review with quantitative empirical research. The literature review allowed us to define the terms to be used in the empirical study and recognize the research problem concerning I4.0 technologies, the scope of companies' digital maturity, and their GVC engagement. In other words, this phase of the research procedure helped in data operationalization, formulation of research proposals, and gathering insight for preparing questions for computer-assisted telephone interviews (CATI) with company representatives.

According to the Digital Economy and Society Index (DESI) 2022, Poland remains one of the weakest countries in terms of digital competitiveness among all the EU member states. As a country from the CEE region, Poland lags behind *e.g*. Czechia, Hungary, and Slovakia, and just slightly overtakes Romania and Bulgaria (DESI, 2022). Recent available DESI 2022 shows that despite continuous progress much work in the area of digital transformation is required. Poland is still catching up in terms of the digitalisation level compared to other EU Member States. Digital Economy and Digital Society Index (DESI, 2022) published by the European Commission, Poland ranks 24th among all Member States in terms of digital development (https://digital-strategy.ec.europa.eu/pl/policies/desi-poland).

According to data analysed by the European Commission, the SME sector in Poland is characterised by a much lower rate of digital technology use – at least at a basic level – than the EU average (40% of SMEs in Poland vs. 55% EU average). It is possible to notice a significant backlog of Polish enterprises in the area of the use in their activities regarding social media, big data, cloud solutions, artificial intelligence (AI), and the use of e-invoices. There is also a large gap in the digital skills of Polish society in relation to communities in other member states. The data show that there is a particular need for measures to support small and medium-sized enterprises in digital transformation. The construction of advanced 5G networks is also important. Poland achieved the best result (22nd place) in the category of digital public services, thanks to a high score on the 'open data' indicator.

The state of digitisation of Polish enterprises can also be assessed on the basis of data from Statistics Poland (SP). Although access to the Internet in 2021 was declared by almost all enterprises in the industrial processing sector (98.4%), only 34.3% of enterprises in this sector used software supporting the flow of information between employees (ERP software). An even smaller percentage of companies in the manufacturing industry (31.6) declared that they used a CRM system to collect and store customer information.

Moreover, despite Poland's effective open data policy, only 15.3% of manufacturing companies used public data relating to the state of the economy and finances in 2021. In the same year, paid cloud services were used by 28.7% of enterprises, which invested mainly in services that consisted of providing access to email or office software (*e.g.* spreadsheets and word processors). In 2021, less than 19% of enterprises were using Internet of Things technology. The majority (51.2%) were large entities. On the other hand, less than 3% of enterprises declared the use of AI technology in 2021.

Although the SP data and the DESI 2022 results show that Polish enterprises are significantly behind in terms of the level of digitalisation compared to most member states, it is also evident that there is continuous progress and an increased interest in the use of new technologies among Polish entrepreneurs.

Thus, the relatively low position of Poland in terms of digitalisation justifies further studies on Polish firms' digital maturity and the consequences for the GVCs in which they operate.

We conducted structured CATI with managers who represented 400 industrial manufacturing firms located in Poland. We interviewed the participants from November 2019 to January 2020. Before the main study, we conducted a pre-research study. Firstly, to check the adequacy and intelligibility of the questionnaire, and secondly, to indicate the type of managers that should partake in the main measurement. We used the same research methods both the pre-research and the main study. Finally, we

conducted CATIs with managers responsible for the companies' international activities and those familiar with the new technologies in their companies' GVCs. We used the same selection criteria for companies both in the pre-research and main study. The managers in both studies were informed about the main purpose of the project. Moreover, the interviewers explained how new technologies are understood in the study so that all interviewees would have the same definition of the main aspects used in the project. One of the overall conclusions formulated after the pre-research study was that the managers had general knowledge concerning the situation on the market and almost all could share information about their partners. The research tool was a questionnaire with 24 questions.

Companies Profile

We conducted the study among firms representing industrial manufacturing small, medium, and large entities, according to NACE Rev. 2.0. Exactly 5.6% of firms were entities employing from 10 to 49 people, 15.4% – from 50 to 249 people, 12.8% – from 250 to 499, while 66.3% – the majority – were large enterprises with 500+ employees. The size structure of the sample corresponded with the involvement of particular types of enterprises in Poland – in terms of their size – in R&D operations, according to Statistics Poland (2020). The studied companies were selected randomly. We measured prevalence (p), *i.e.* the proportion of the population that had a specific characteristic in a given period, and the result was 0.663, which meant the share of the largest enterprises in the population. We assumed that the margin of error (e) was 5%, which conveyed the percentage that described how close the survey is expected to be relative to the real population value. The sampling confidence level showed the reliability of the research, which in this case was 90%, expressed as a percentage that showed the level of certainty in how accurately the sample reflected the population in the selected confidence interval.

The studied firms represented the whole manufacturing sector; Section C according to NACE Rev. 2.0, stemmed from the private sector (97.3%). The vast majority were Polish companies in terms of the ownership structure of capital (76.3%). These were established businesses with 11–15 years of history of operations in the Polish market. Their production facilities were mostly located in urban agglomerations. Nearly 90% of them were active exporters.

Variables

To assess firms' digital maturity of firms, we asked about the intensity of adoption of eleven different I4.0 technologies, *i.e.* autonomous robots, big data analytics, digital twin, internet of things, horizontal and vertical integration, cybersecurity, cloud computing, additive manufacturing, virtual reality, mobile technologies, and social media. While investigating the digital maturity of companies, the study referred to the list of I4.0 technologies indicated by Rüßmann *et al.* (2015), and we developed the set by adding social media solutions and mobile technologies. We asked the managers who represented the companies to use a five-point Likert scale for assessing the adoption of eleven I4.0 technologies, in which 1 stood for – 'we do not use it at all,' 2 – 'we use it very rarely,' 3 – 'we use it rarely,' 4 – 'we use it often,' 5 – 'we use very often. '

Awareness of Partners' Progress in Digital Transformation and Their Integration Attempts

We measured the awareness of the partners' progress in digital transformation using four indices that referred to suppliers, buyers, substitute providers, and competitors. We first asked the managers representing the studied firms to diagnose their knowledge about the risks, challenges, opportunities, and activities that accompanied the adoption of I4.0 performed by their partners. The challenges, risks, and opportunities were indicated, and the managers were to express if they agreed or not whether these elements appeared. They were asked to use a five-point Likert scale to assess whether they 1 – 'strongly disagree,' 2 – 'disagree,' 3 – 'it is difficult to say,' 4 – 'agree,' or 5 – 'strongly agree.' To assess the managers' awareness, we considered responses 1, 2, 4, and 5. We did not consider response 3. To learn about the integration attempts, we asked the managers whether their firms undertake such actions, which we measured with the five-point Likert scale as above.

GVC Changes Facilitated by The Adoption of I4.0 Technologies

Changes in GVCs were associated with 1) entering new sectors which meant diversification; 2) undertaking new functions in the GVC, which entailed changes in governance; and 3) space extension, which meant geographical expansion. The changes were evaluated on a five-point Likert scale, in which 1 stood for 'the partner does not implement the change at all,' 2 – 'the partner probably implements the change,' 3 – 'it is difficult to say if the partner implements that,' 4 – 'the partner implements the change,' 5 – 'the partner implements the change for sure. '

Analytical Strategy

While developing this analytical strategy, we followed the reasoning of Knight *et al.* (2021) to conduct exploratory research. Figure 1 depicts the overview of the conducted research problem and Figure 2 – the analytical scheme.

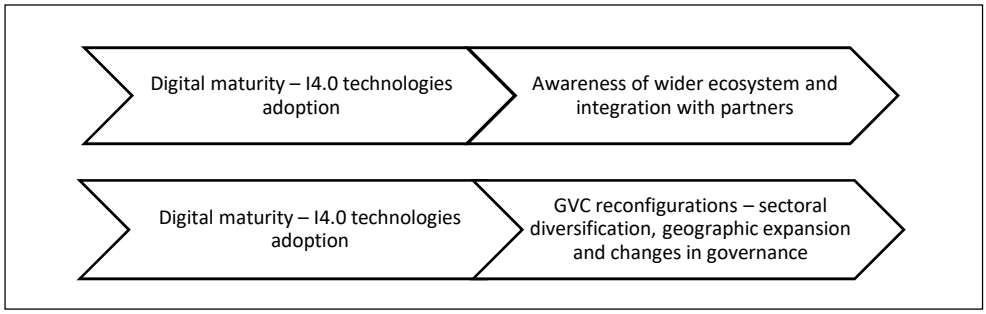

Figure 1. Overview of the research problem
Source: own elaboration.

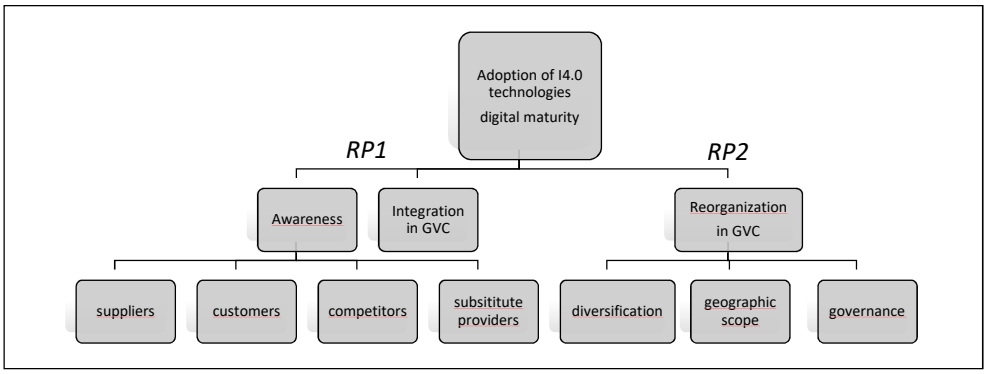

Figure 2. The analytical scheme presenting the interdependencies among the variables and the research proposals
Source: own elaboration.

The first step in the analysis was to assess the level of I4.0 technology adoption (digital maturity) by the interviewed companies. In the next part, we performed a two-step cluster analysis to identify patterns in the adoption of I4.0 technologies in enterprises. We measured the adoption assessment of the I4.0 solutions with basic descriptive statistics calculated together with the Kolmogorov-Smirnov test, which examined the distribution normality. Next, we calculated descriptive statistics for the challenges, opportunities, and threats related to the adoption of I4.0 technologies by suppliers, customers, substitute producers, and competitors of the interviewed companies.

In the next part of the analysis, we checked the correlation between the level of digital maturity of the interviewed companies and their awareness of challenges, risks, and opportunities related to the adoption of I4.0 technologies by their partners. For this purpose, Spearman 's rho correlation analyses were performed. We used a similar methodological approach to identify the changes facilitated by the

adoption of I4.0 technologies in the companies' GVCs, for which we referred to descriptive statistics indicators. Furthermore, we used Spearman's rho correlation index to establish the relationship between the level of digital maturity of the interviewed companies and the changes they introduced in their GVCs.

RESEARCH METHODOLOGY

Digital Maturity Assessment

Table 1 presents the level of I4.0 technology adoption. As indicated by the minimum and maximum values of the level of I4.0 technologies adoption, the intensity of using these solutions among the interviewed companies ranged from 1 – 'we do not use it at all' to 4 – 'we use it often' and 5 – 'we use it very often.' The average and median values showed that companies most extensively used only solutions in the field of cybersecurity and social media.

Table 1. The level of I4.0 technology adoption

I4.0 technologies	M	Me	SD	Min.	Max
Big data analytics	1.65	1.00	1.00	1.00	5.00
Autonomous robots	1.32	1.00	0.95	1.00	5.00
Simulation (digital twin)	1.98	1.00	1.40	1.00	5.00
Horizontal and vertical system integration	1.39	1.00	0.95	1.00	5.00
Industrial Internet of Things (IoT)	1.31	1.00	0.79	1.00	4.00
Cybersecurity	4.35	4.00	0.65	1.00	5.00
Cloud computing	3.05	3.00	1.14	1.00	5.00
Additive manufacturing (3D production)	1.35	1.00	0.80	1.00	4.00
Augmented reality	1.19	1.00	0.61	1.00	4.00
Mobile technologies	2.19	2.00	1.08	1.00	5.00
Social media	3.53	4.00	1.07	1.00	5.00

Source: own study.

We performed a two-stage cluster analysis to identify patterns of using digital solutions in enterprises. The conducted analysis showed that two clusters could be distinguished based on the introduced variables (Table 2). The average value of the silhouette measure of consistency and distinctiveness was 0.2, which means that the quality of the identified groups was correct. Thus, the analysis allowed us to distinguish two groups: the first cluster included 333 companies (83.2% of the interviewed companies), while the second group included 67 companies (16.8%).

The most important predictors in the model turned out to be augmented reality (virtual reality), additive manufacturing (3D production), and simulation (digital twin). Autonomous robots and the industrial Internet of Things (IoT) followed. The least important in distinguishing clusters turned out to be mobile technologies, big data analytics, horizontal and vertical system integration, cloud computing, and cybersecurity.

The first group included mostly enterprises that often use cloud computing solutions and cybersecurity but do not use any other type of technological solutions studied.

The second cluster included mainly entities that also often use both solutions used in the case of companies from the first cluster, but they additionally often employ such technologies as simulation (digital twin) and – albeit rarely – additive manufacturing (3D production) and mobile technologies (Table 2).

The comparison of Cluster 1 and Cluster 2 in terms of the use intensity of the proposed I4.0 technologies showed that Cluster 2 included a lower percentage of the studied sample, but in relation to the three technologies, it showed a higher intensity of use than Cluster 1. Therefore, Cluster 1 comprised entities with a lower, and Cluster 2 – with a higher degree of digital maturity. Companies considered to be more digitally mature were entities that distinguished themselves with the use of simulation (digital twin), additive manufacturing, and mobile technologies.

In the last step of this part of the analysis, we checked the distribution of the quantitative variable, *i.e.* firms' digital maturity (Table 3).

Table 2. Cluster of firms and the level of adoption of I4.0 technologies

Variable	Significance of predictors	Cluster 1 – Laggards (n = 333; 83.2%)	Cluster 2 – Leaders (n = 67; 16.8%)
Augmented reality	1.00	They do not use it at all (98.8%)	They do not use it at all (46.3%)
Additive manufacturing (3D production)	0.98	They use it very rarely (92.2%)	They use it rarely (37.3%)
Simulation (digital twin)	0.97	They do not use it at all (77.5%)	They use it often (71.6%)
Autonomous robots	0.78	They do not use it at all (96.7%)	They do not use it at all (52.2%)
Industrial Internet of Things (IoT)	0.70	They do not use it at all (93.4%)	They do not use it at all (41.8%)
Mobile technologies	0.07	They do not use it at all (33.9%)	They use it rarely (31.3%)
Big data analytics	0.06	They do not use it at all (67.3%)	They use it rarely (46,3%)
Horizontal and vertical integration	0.03	They do not use it at all (85.6%)	They do not use it at all (76.1%)
Cloud computing	0.02	They use it often (55.0%)	They use it often (61.2%)
Cybersecurity	0.01	They use it often (38.1%)	They use it often (44.8%)

Source: own study.

Table 3. Level of I4.0 technologies adoption (digital maturity index): basic descriptive statistics of the studied variables together with the Kolmogorov-Smirnov test [N=400]

Statistics:	M	Me	SD	Sk.	Kurt.	Min.	Max.	D	p
Digital maturity index :	23.30	22.00	4.92	1.02	1.62	11.00	43.00	0.12	<0.001

Note: M – mean; Me – median; SD – standard deviation; Sk – coefficient of skewness; Kurt – kurtosis, Min. – minimum value; Max. – maximum value; D – Kolmogorov-Smirnov statistic; p – significance level.
Source: own study.

The median for the level of I4.0 technology adoption was higher than the average, which indicated a positively skewed distribution. The results of the Kolmogorov-Smirnov test emerged as statistically significant, which proved that the distribution of the variable differed significantly from the normal distribution.

Digital Maturity Versus Awareness of Partners' Progress in Digital Transformation and Integration Attempts

The digital maturity of the interviewed entities could be evidenced by the number and diversity of I4.0 technologies adoption, albeit to more thoroughly diagnose how much a firm is digitally mature, the study should consider its awareness and understanding of the challenges, opportunities, and risks posed by the I4.0 technology among its partners in the same GVC. Partnership in the same GVCs is characterized not only by flows of material goods and services but also by the exchange of knowledge and ideas, not to mention sharing diverse perspectives. It turned out that thanks to the adoption of I4.0 solutions, suppliers of the studied firms enjoyed greater chances of joining GVCs (M=3.55), and they noticed the risk of losing their position in GVCs (M=3.14; Table 4). The I4.0 technologies adoption offered them chances to increase sales (M=4.14) and upgrade the competitiveness of buyers (M=4.29). For substitute providers, I4.0 technologies represented a chance to improve innovation performance and better exploit existing technologies (both M=3.37). Competitors were aware of the pressure on investment in new equipment, machines (M=3.97), and the development of proper skills among their workforce (M=3.92).

Table 4. Chances, threats, and challenges for partners: The perspective of the studied companies [N=400]

Suppliers	**M**	**Me**	**SD**	**Min.**	**Max.**
Industry 4.0 technologies create the pressure on standardisation of processes.	3.05	3.00	1.01	1.00	5.00
Industry 4.0 technologies are a threat to the position in the GVCs.	3.14	3.00	1.02	1.00	5.00
Industry 4.0 technologies are a chance to reduce costs.	3.08	3.00	1.01	1.00	5.00
Industry 4.0 technologies are a chance to join GVCs.	3.55	4.00	1.03	1.00	5.00
Buyers	M	Me	SD	Min.	Max.
Industry 4.0 technologies create pressure to look for new distribution channels.	1.90	2.00	0.72	1.00	4.00
Industry 4.0 technologies are a threat to their present economic benefits.	2.55	2.00	0.99	1.00	4.00
Industry 4.0 technologies are a chance to increase their sales.	4.14	4.00	0.64	2.00	5.00
Industry 4.0 technologies are a chance to upgrade their competitiveness.	4.29	4.00	0.70	2.00	5.00
Substitutes' producers	**M**	**Me**	**SD**	**Min.**	**Max.**
Digitalization is a threat to present business models	2.63	2.00	0.93	2.00	4.00
Industry 4.0 technologies create pressure on investment.	3.18	4.00	1.11	1.00	5.00
Industry 4.0 technologies are a chance to improve innovation performance.	3.37	4.00	1.40	1.00	5.00
Industry 4.0 technologies are the opportunity to better exploit their existing technologies	3.37	4.00	1.37	1.00	5.00
Competitors	**M**	**Me**	**SD**	**Min.**	**Max.**
Industry 4.0 technologies are a chance to reduce costs	2.77	3.00	0.89	1.00	5.00
Industry 4.0 technologies are a chance to reduce the time needed to complete processes	3.30	4.00	1.25	1.00	5.00
Industry 4.0 technologies create pressure to spend more on the training of the professional workforce	3.92	4.00	0.98	1.00	5.00
Industry 4.0 technologies create pressure to increase investment outlays	3.97	4.00	1.02	1.00	5.00

Source: own study.

Table 5 presents the basic descriptive statistics for the awareness of the progress in digital transformation among suppliers, customers, substitute providers, and competitors of the studied firms. The results of the Kolmogorov-Smirnov test turned out to be statistically significant, which proved that the distribution of the variable significantly differed from the normal distribution.

Table 5. Index of awareness of the partners' progress in digital transformation [N=400]

Awareness of progress in digital transformation among:	**M**	**Me**	**SD**	**Sk.**	**Kurt.**	**Min.**	**Max.**	**D**	**p**
Suppliers	6.94	8.00	2.69	-1.23	0.20	0.00	9.00	0.23	<0.001
Customers	3.87	4.00	0.57	-5.01	26.29	0.00	4.00	0.53	<0.001
Substitutes' Producers	5.91	6.00	0.44	-6.82	53.67	2.00	6.00	0.52	<0.001
Competitors	15.68	16.00	2.79	-1.10	2.07	0.00	19.00	0.15	<0.001

Source: own study.

Managers were the most aware of the challenges, opportunities, and threats generated by the I4.0 technologies adoption for the studied firms' competitors (M=15.68, Me=16.00) and the least aware of the situation of their own customers (M=3.87; Me=4.00).

In the next part of the analysis, we checked whether there was a correlation between the level of digital maturity of the studied companies (the index in Table 2) and their awareness of the challenges, risks, and opportunities related to the implementation of I4.0 technology by their partners (the indices in Table 5). To verify the first research proposal (RP1), we used Spearman 's rho correlation analysis (Table 6).

Table 6. Correlation coefficients between the awareness of the partners' progress in digital transformation and the interviewed companies' digital maturity [N=400]

Awareness of the progress in the digital transformation of:	Correlation coefficients	
Suppliers	*rho* Spearman	0.12
	significance	0.020
Customers	*rho* Spearman	-0.05
	significance	0.319
Substitutes Producers	*rho* Spearman	0.01
	significance	0.784
Competitors	*rho* Spearman	-0.02
	significance	0.653

Source: own study.

The analysis showed that only the level of awareness about digital transformation among suppliers correlated in a statistically significant way with the digital maturity index of the studied companies. This correlation was weak but positive. It meant that the greater the digital maturity of the studied firms, the higher their awareness of the progress in the digital transformation of their suppliers. The remaining tested compounds turned out to be statistically insignificant. Thus, the results agree only with the RP1Aa.

Moreover, the digital maturity of enterprises was evidenced by the efforts made to integrate the partners with whom the entity cooperated in GVCs. Therefore, we checked whether the adoption of I4.0 solutions by the interviewed companies correlated with attempts to integrate their partners in GVCs. The analysis of Spearman 's rho correlation showed a positive and strong relationship between variables (rho = 0.50; $p < 0.001$), which meant that the more advanced the enterprise was in the use of digital solutions, the more managers recognized that their company strives to integrate its partners. Thus, the results agree with the RP1B.

As part of the study, we attempted to determine how much the implementation of digital solutions was associated with changes in the GVC in which the surveyed company participated. We checked whether the adoption of I4.0 technologies was associated, first, by assuming increasingly more diverse functions in the GVC, which epitomized the changes in governance. Secondly, we investigated whether the companies entered new sectors of activity, which would translate into increased diversification. Thirdly, we checked whether the companies expanded their geographical area of activity, which was associated with assuming activities on a global scale (Table 7).

Table 7. Changes in the GVCs implied by the adoption of I4.0 technologies [N=400]

Changes in GVC	M	Me	SD	Min.	Max.
The firm enters new business sectors.	2.31	4.00	0.71	1.00	5.00
The firm tries to operate globally.	4.23	4.00	0.80	2.00	5.00
The firm performs more diverse and sophisticated operations.	3.70	4.00	0.88	2.00	5.00

Source: own study.

The analysis of means and middle values showed that most respondents agreed their companies perform more diverse functions – which means changes to the governance of GVCs (M=3.70) – and try to act globally (M=4.23). In the last step of this part of the analysis, we verified whether the level of digital maturity correlates with changes in GVCs. The results of Spearman's rho correlation analyses are presented in Table 8 below.

The analysis showed that all tested compounds were statistically significant and positive. Moderately strong correlations occurred between the level of digital maturity and changes in the governance of GVCs. Weak correlations were linked to changes in the spatial scope of operations. Thus, the second research proposal (RP2) was reflected in the obtained results. Nevertheless, the greater digital maturity of the firms accompanied the diversification of functions implemented in the value chain (governance) rather than their actions in new sectors or geographic expansions associated with operating on a global scale.

Table 8. Correlations between the level of digital maturity and changes in the GVCs of interviewed companies

Changes in GVC	Correlation coefficients	
The firm enters new business sectors.	*rho* Spearman	0.10
	significance	0.038
The firm tries to operate globally	*rho* Spearman	0.17
	significance	<0.001
The firm performs more diverse and sophisticated operations	*rho* Spearman	0.38
	significance	<0.001

Source: own study.

CONCLUSIONS

Early studies on I4.0 concentrated on technology adoption. Later research dealt with organizational adjustments, recognized as the complementary and necessary elements of digital transformation. The study went further to demonstrate the wider consequences of the I4.0 adoption on partner relationships in GVCs. We do not claim readiness differs due to GVC but that it is a key factor that needs to be taken into account, accounting for supply partners and other actors in the company's network so far neglected deserve particular attention as I.40 or digital transformation does not happen in a vacuum but is inherently related to firm 's relationships (*e.g.* inspired, motivated or forced and required by partners). Available studies stress the importance of I4.0 GVC implications, *e.g.* new technologies provide new options for dispersed modular activities, yet they allow the shortening of production stages (Strange & Zuchella, 2017). Processes may increase the power of MNEs as coordinators of GVC, or conversely, empower many small geographically scattered networks or chain members (UNCTAD WIR, 2017). Additive manufacturing (AM) related to I4.0 can disrupt the configurations and operations of IB; the specific continuum of household – to global-level manufacturing (Hannibal & Knight, 2018). Basically, digitization influences internationalization in terms of timing, pace, rhythm, location and entry mode; it questions the basic notions about the configuration of global production (Coviello *et al.*, 2017). Luo and Zahra (2023) highlight that the Fourth Industrial Revolution is rife with challenges, and firms must 'remake' themselves and rethink the concept of the firm and its boundaries to thrive in this new environment (Ancarani *et al.,* 2019). Moreover, the Fourth Industrial Revolution expands the ways of bundling and leveraging FSAs and CSAs and changes the ways MNEs monitor global operations and mobilize global resources.

The focus on digital transformation goes beyond the implementation of technological innovations so as to consider their impact on the companies' external partners in GVCs. By drawing on the Polish 400 manufacturing companies, the article examined how I4.0 technology adoption modifies the awareness of partners' progress in digital transformation, affects the integration with GVC partners, and leads to changes in the diversification, geographic scope, and governance of value chains. In that way, we illuminated how the disruptive innovation of the I4.0 wave in one firm sends ripples that affect other entities and their partners along the value chain they jointly create.

The study offers a compelling case that opens space for further discussion and rethinks, firstly, how to assess the digital maturity of companies that operate together in the GVC. Secondly, how I4.0 technologies and their adoption by partners operating in one GVC impact the GVC.

After examining the adoption of 11 I4.0 technologies, we found that it is not just the level of their adoption itself that matters for digital maturity but the broader awareness of progress in digital transformation among partners. Despite intensive work on standardization – how to measure the digital maturity of firms – there is no one-size-fits-all strategy that suits all businesses or industries. It means that the I4.0 roadmap for each company is highly idiosyncratic, and it should be devised by drawing on each company's core competencies, strengths, motivations, capabilities, intent, goals, priorities, and budgets (Ghobakhloo, 2019). Thus, what seems inevitable is the enlargement of the I4.0 domain from a purely technological focus to a broader scope that would cover the whole organization. For instance, instead of measuring technology adoption levels, one could use broader intelligence and awareness concerning the GVC partners as an indicator of I4.0 readiness.

Specifically, we posit that the level of I4.0 technology adoption resonates with the companies' awareness of their suppliers' digital progress. There exists an interdependence between the level of I4.0 technology adoption and the knowledge of the related opportunities or threats for the firm 's suppliers. After all, we confirmed research proposal 1A only for suppliers. Thus, the more companies are digitally mature in terms of I4.0 technology adoption, the more they know about the challenges experienced by their suppliers. This diagnosed correlation contributes to the debate on how outside thinking may accelerate business model innovations (cf. Wu *et al.*, 2021). The knowledge of the challenges, risks, and opportunities facilitated by I4.0 technologies that the suppliers face may direct companies toward particular business model innovations. Simultaneously, this research can add to the discussion on the impact of the digitization of GVCs, as an important aspect of GVC studies (Kano *et al.*, 2020).

Furthermore, the study elucidated that companies adopting I4.0 solutions know they must develop common standards with their partners, so they try to integrate the partners in GVCs. Thus, research proposal 1B fully resonates with the obtained results. The empirical findings showed that I4.0 technologies facilitate reconfigurations in GVCs in terms of diversification, spatial expansion, and governance, which translates to business model innovations (cf. *e.g.* Kumar & Srivastava, 2020; Sharma *et al.,* 2019). Moreover, we found that the adoption of I4.0 technologies facilitates changes in company business models, which translates into reconfigurations in their GVC, which fully reflects research proposal 2.

The examination of I4.0 technologies adopted by the studied companies revealed that the entities develop their digital maturity gradually, which agrees with other studies that found different types of companies engage in digital transformation with varying degrees (*i.e.* Müller *et al.,* 2018). The conducted research foregrounded two different types of entities in terms of their adoption of I4.0 technologies, *i.e.* leaders and laggards. Laggards are companies that adopted diverse cybersecurity solutions and exploited cloud computing. Leaders are firms that adopt more sophisticated technologies. Thus, cybersecurity issues represent the prerequisite to becoming more digitally mature. Moreover, the impact of digital transformation on the transformation of their business models may be gradual in nature.

The findings obtained speak to one of the most timely and significant discussions on how to properly assess the digital maturity of firms that today operate in GVCs. Being part of a constellation means being interdependent. Thus, it does not suffice for a firm to digitally transform its own organization, as it also requires the firm to partly contribute to the digital transformation of its partners. Otherwise, the digital progress of the company will be wasted or not fully utilized. The novelty of the presented study is to some extent related to the context, namely the post-transition economy of Poland, which remains digitally less mature than other European countries.

Furthermore, Polish companies remain poorly researched in terms of the Digital Revolution. Firms in post-transition countries such as Poland are exposed to harsh competition from firms all around the globe and faced with a globalization-deglobalization narrative (Witt, 2019), 'wicked problems' (Rašković, 2022) new types of risks, such as populism, nationalism, and xenophobia (Lonergan & Blyth, 2020; Hartwell & Devinney, 2021), or technonationalism (Luo, 2022) and they need to swiftly adapt and adjust to standard and general patterns which govern international business activities. Nevertheless, their legacy of representing previously a communist regime and the fact they exemplify the country seen as a unique research laboratory (magnitude of changes, cultural heritage) make them quite atypical – suffering liability of latecomers, being less advanced and endangered by middle-income trap – all this requires a special attention. By referring to the context of a post-transition country, we demonstrated that the progress in digital transformation at the microeconomic level – which may be measured by diverse digital maturity indices and is reflected in the innovation performance of firms – does not happen in a vacuum, and the peculiarity of a post-transition economy related to its institutional and cultural specificity plays a considerable role. The empirical findings reported here can serve as a basis for future theory building and, then, testing how to measure the digital maturity of firms and how to recognize its implications for business models. Research can extend this analysis of responses of companies to the challenges that I4.0 technologies pose for them and their partners, thus, how to keep pace with the 4IR not only as a single company with its own business model but as a part of a whole GVC. Keeping in mind that business model alterations imply changes in the business models of the firm 's partners, future studies must consider more than individual firms.

The 4IR that claims close network relations and compatibility are prerequisites for future international business cooperation in GVCs and can be seen as an extension of another approach forwarded by the European Commission, which applies DESI. This composite index tracks the evolution of EU member states in digital competitiveness. Acknowledging that the sheer increase of ICT use and improvement in indices of digital economies do not guarantee to reap concrete economic and social benefits. Just as the availability of hardware, software, and the development of ICT infrastructure must not necessarily translate into real economic growth and an increase in social welfare, so pure facts and figures on computers, the Internet use by firms, and the availability of cloud computing must not necessarily enable and safeguard collaboration among partners along value chains.

The key limitation of the conducted study is that CATI is drawn on a five-point Likert scale. We focused on manufacturing companies, *i.e.* NACE Section C without considering differences in market structures and other factors that may influence companies' performance and their relationships with the studied technologies, such as companies' and GVCs' structures, product characteristics, or organizational cultures. Future research would require in-depth interviews, which would allow us to better confront interviewees' declarations with processes that occur in the studied companies. Moreover, the set of I4.0 solutions must be broadened in future studies to incorporate the most recent technologies such as blockchain, NFT, general tokenization, fintech structures, and the metaverse. These technological solutions strongly impact companies and supply chains. Furthermore, we are aware of complementarities among the studied technologies, so in the future, the effect of technology combinations in different industry sectors needs adequate analysis.

The adopted approach considered the intensity and extension of I4.0 technologies adoption, as we asked 'How many out of the 11 technologies are used?' and 'How much (Likert scale) these technologies are used (intensive and extensive aspect)?' The digital maturity or readiness index could be three-dimensional, accounting not only for the intensity of application (how often?) or the number of technologies adopted (how many?) but also for the functional aspects of the adoption (for what purpose?

To conclude, the novelty of the study lies in the comprehensive and systematic investigation of the impact of I4.0 technologies adoption on companies that operate in GVCs. This article focuses on the disruption caused by the advancement of digital transformation in companies that operate in a constellation of relationships (Cuypers *et al*., 2020) and are interdependent in the same GVC. It recognizes the relationships within the GVC as channels of transmission of challenges, risks, and opportunities that emerge from the disruption.

In this study, we touched upon the case of a post-transition, post-communist country in Central and Eastern Europe under digital transformation, which is highly specific yet offers valuable findings transferable to other economies on the eve of the Fourth Industrial Revolution. The presented study contributes to current studies on I4.0, which mostly focus on the most advanced countries-leaders in implementing Industry 4.0, thus neglecting the less advanced economies. In the last decade, I4.0 has garnered much attention among scholars and industry practitioners, but the research landscape of I4.0 implementation remains fragmented. Given the deficit of studies on the CEE region and I4.0, this article can contribute to the emerging literature by addressing the above research gap.

Thanks to the conducted study on the digital maturity of firms from a post-transition country, we demonstrated that I4.0 is a concept that still requires conceptual development. Following the reasoning of Golini and Kalschmidt (2019), we aimed to bridge the global value chain approach and the issue of I4.0 by focusing on the perspective of single companies. Thus, the study elucidated that the emerging theory of the 4IR is interdependent with the theory of GVCs.

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