Marta Götz
Vistula University
e-mail: m.gotz@vistula.edu.pl
ORCID: 0000-0002-8764-871X

Marta Mackiewicz
SGH Warsaw School of Economics
e-mail: marta.mackiewicz@sgh.waw.pl
ORCID: 0000-0002-7447-0887

DOI: 10.15290/oes.2025.03.121.14

I4.0 AND 4XE – INDUSTRY 4.0 AND CLUSTER POLICY: EXPLOITATION, EFFECTIVENESS, EVALUATION, AND EXPECTATIONS

Summary

Purpose | This article analyses the impact of cluster membership on businesses' digital transformation and adoption of Industry 4.0 technologies, with a focus on benefits and varying member approaches.

Research method | The study combines the literature review with the results of Benchmarking and the application of R software to develop typologies of cluster members based on four dimensions [4xE]: Exploitation, Effectiveness, Evaluation, and Expectations concerning I4.0 adoption.

Results | The results show that cluster initiatives positively influence the adoption and use of advanced technologies. The identified member typologies highlight varying engagement levels and benefits.

Originality/value/implications/recommendations | This research contributes to the understanding of cluster dynamics in fostering technological advancements and offers evidence-based recommendations for enhancing digital transformation support within clusters. Insights are provided for cluster coordinators to tailor support initiatives for specific member groups, improving the effectiveness of I4.0 adoption.

Keywords: Clusters, cluster policy, digital transformation, Industry 4.0

JEL classification: M0, R10, O3

1. Introduction

The analysis of digital transformation including the implementation of Industry 4.0 technologies and processes cannot be conducted in isolation from the regional and local context [Fraske, 2022]. Implementing Industry 4.0 solutions, which is associated with numerous opportunities to improve efficiency and innovation [Pelle et. all 2022; Morisson and Pattinson, 2019; Ortt, et al. 2020; Buchi, et al, 2018], requires, however, overcoming several barriers [Hervás-Oliver, et al., 2020; McPhillips, 2020] and for the entities implementing them, it means several challenges [Gagnidze, 2022; Hervás-Oliver, 2021; Fiorini et al., 2023]. Dealing with them often involves the need for cooperation or reaching for support of specialised entities, hence the idea of establishing digital innovation hubs [DIH] [Hervás-Oliver et al., 2020]. Clusters can play a special role in these processes and research to date confirms this potentially stimulating function, highlighting both the institutionalised as well as informal spontaneous aspects, stressing the multiple benefits clusters can provide and revealing how they can facilitate the digital transformation of their members [Jankowska et al., 2021; Götz, 2021].

In this article, the authors try to identify the importance of Polish clusters, in particular the institutionalised assistance provided, for entities interested in the implementation of Industry 4.0 processes. Based on a Benchmarking study [PAED, 2023], the authors seek to propose typologies of cluster members with respect to the four dimensions of cluster assistance available for advancing digital transformation. This allows us to reveal the dominant group for each possible classifications which account for the levels of Exploitation by cluster members of cluster aid towards digital transformation, Effectiveness of such assistance, Evaluation of obtained aid, and Expectations regarding the future importance of I4.0.

The added value of this research is the up-to-date identification of the specificity of Industry 4.0 implementation processes in Polish clusters, as well as the identification of potential in this respect, i.e. the role attributed to clusters as catalysts of these processes. In this way, they can complement the existing literature – on the one hand, the Polish literature, which usually discusses Industry 4.0 in isolation from the cluster context, and on the other hand, the

extensive international literature, enriching it with knowledge from Poland – a post-transformation system country, classified as low/moderately digital or hesitant, catching up digitally economy [Castelo-Branco, Cruz-Jesus, Oliveira, 2018; De Propris, 2018].

The extant literature provides evidence for the potential positive role of cluster organisations in the processes of digital transformation. Owing to the complexities of these processes associated with the adoption of I4.0 and the surrounding challenges faced in this respect mainly by small and medium firms, the availability of dedicated, effective, and efficient professional support cannot be overestimated. Yet, a certain research gap can be diagnosed. Whereas, most studies in this area discussed various aspects of such assistance, including the identification of causalities in selected clusters or the relevance of certain variables [Capone et al., 2023; Hervas Oliver 2022; Hervas Oliver, et al., 2021; Sedita & Ozeki, 2021], to the best of this knowledge they missed the attempts to offer some classification of the cluster members or unearth the regularities in the area of "cluster I4.0 support" and the "effects for cluster members". Thus, the authors tried to bridge this gap, at least to some extent, by exploring the Polish clusters to identify regularities and to discover patterns and, in consequence, providing a classification of cluster members, which would link aspects such as the usage of assistance, its effectiveness or evaluation. In that way, the authors hope that they can enrich the existing literature and advance this knowledge regarding the professional clusters' role in the processes of digital transformation. Such typologies which would reflect the dominant regularities among cluster members might offer valuable insight into the prevalent profile and hence provide some basic evidence for subsequent design of the support and implementation of concrete measures.

This paper is structured as follows: the review of relevant literature is presented at first in order to highlight the potential clusters' contribution to the digitalisation processes. The next section outlines the adopted methodology, the conducted analysis, and briefly presents the results using graphs that illustrate the emerging classification of cluster members. The final section offers an in-depth discussion of the established typology and concludes with a consideration of the study's limitations and a brief overview of its added value.

2. An overview of the literature

The emergence of new technologies in successive waves fundamentally alters the utilisation of resources and their modes of application, prompting a restructuring of production organisations. This dynamic process leads to the creation of novel sectors while rendering others obsolete. Consequently, it acts as a reset mechanism for the economy, igniting growth once more. This transformative impact extends beyond economic realms, affecting consumption patterns, market access, and lifestyles. Thus, the authors contend that each wave ushers in disruptive changes across both the economic and societal domains [De Propris & Bailey, 2021].

In essence, the true transformative force is believed to lie in digital technology, with its pervasive application anticipated to revolutionise both products and processes while simultaneously reconfiguring supply chains [Baur and Wee, 2015; Schmidt et al., 2015; Germany Federal Ministry of Education and Research, 2015]. Any company operating within an Industry 4.0 framework undergoes substantial technological transformations. Consequently, Industry 4.0 should be perceived as a dynamic and continuously evolving concept [Ferrás-Hernández, 2020]. However, according to Guilherme Sanches Contieri et al [2021] Industry 4.0 is one of the most heterogeneous waves of global industrialisation and the impact of new technologies in the industry is not clear.

Fernandez-Escobedo et al [2023] introduce the concept of a digital industrial cluster [DIC], designed as a novel policy tool for future economies influenced by digital technologies and Industry 4.0. It extends the traditional industrial cluster concepts to digital phenomena. Through a discursive and theoretical analysis, including a literature review on industrial clusters' adaptation to digital transformation, the authors compare the DIC to existing digital agglomeration policy tools, highlighting similarities, differences, and advantages.

Benitez et al. [2020] highlight the importance of adopting an ecosystem perspective over a traditional linear supply-chain model in the context of Industry 4.0 solutions. They emphasise that the primary objective within the evolutionary view of Industry 4.0 ecosystems should focus on intelligent business solutions, not merely the supply of technology.

Gillai et al. [2020] found that while the organisational and environmental contexts influence the adoption of digital manufacturing technologies (DMTs), these effects are filtered through the technological framework of the company. This suggests that successful implementation of DMTs demands more than just the availability of technologies; it requires the right organisational structure and environment.

Public policy can be helpful, but the risk of policy failure is high. Therefore, public policy should target those regions that have related I4.0 capabilities, as these provide local assets that might be exploited to make the policy effective [Balland & Boschma, 2021].

A comparative analysis of Ontario, Canada, and Massachusetts, US, demonstrates the effectiveness of collaboration policies and methods in advancing Industry 4.0. Baker, Gaspard & Zhu [2021] underscore the significance of four main elements: industrial clusters, the surrounding context, collaborative synergies, and network intermediaries. They suggest that further studies could delve into a broader investigation of how top-down policy strategies interact with regional innovation ecosystems' functioning, along with the impact of market- and stakeholder-driven approaches from the bottom-up.

Clusters play a significant role in facilitating the adoption of Industry 4.0 technologies by companies, acting as catalysts for innovation, knowledge exchange, and technological advancement. The collaborative nature of clusters, combining competencies and resources among member firms, enhances the potential for I4.0 adoption, driving competitiveness and efficiency. Büchi, Cugno, and Castagnoli [2020] discuss how I4.0 provides enabling technologies that offer companies significant opportunities for improved efficiency and increased production capacity. This highlights the potential of clusters to act as environments that foster the adoption of these technologies, leveraging the collective strengths and innovations of their members.

Dyba, Di Maria, and Chiarvesio [2022] underscore the importance of actions taken by regional organisations, including Digital Innovation Hubs, in fostering the adoption of I4.0 technologies in manufacturing companies across Europe. This suggests that clusters, through collaboration and support structures, can

facilitate access to I4.0 technologies and contribute to developing individual strategies for their adoption. Benitez, Ayala, and Frank [2020] posit those industrial commons in the I4.0 context should be co-created, emphasising the ecosystem over traditional supply chains. This reflects the shift towards more integrated and collaborative models facilitated by clusters, which can support the ecosystem approach required for I4.0 innovation.

Jankowska [2021] provides a tangible example with the Aviation Valley in Poland, where the cluster's world-class technological level and the collaboration among its members enhance the attractiveness and effectiveness of adopting I4.0 technologies. This case study reinforces the role of clusters in providing a conducive environment for technological leaders and fostering innovation in the era of I4.0.

Russo et al. [2022] and Hervas-Oliver et al. [2020] further illustrate the critical role of clusters in the digital transformation process, highlighting the importance of regional strengths and collaborative platforms facilitated by Digital Innovation Hubs. These studies demonstrate how clusters contribute to the regional adaptation and diffusion of I4.0 technologies, underlining the necessity of place-based collaboration that responds to local and regional specificities.

As can be assumed from the above, clusters significantly contribute to the adoption of I4.0 technologies by fostering collaboration, facilitating access to technological advancements, and providing supportive ecosystems for innovation. The collaborative dynamics within clusters, along with support from regional organisations and Digital Innovation Hubs, are crucial for overcoming barriers to I4.0 adoption and enhancing firms' competitiveness in the digital era.

Yet, although continuously expanding, the literature on clusters as ecosystems accelerating the digital transomration, seem to neglect the "utlity" aspect. In fact, this study aims to show the missing dimension of the previous research on clusters which apparently tends to ignore the genuine percepetion as expressed by cluster members regarding the cluster organisation's assistance in advancing the I.40. Much attention has been devoted so far to the diversity and multiplicity of actual or hypothetical roles played by cluster organisations in digital transformation. Yet, it remains overlooked how these supportive functions are in fact utilised, perceived, and valued by their real and potential beneficiaries.

3. Research methods

The analyses presented in this paper are based on raw data provided by the Polish Agency for Enterprise Development, which conducts regular nationwide benchmarking studies of cluster organisations. The dataset used in this study originates from the most recent edition of the benchmarking report [Piotrowski et al., 2023], and was made available to the authors in its original, unaggregated form for the purpose of the independent analysis. The raw dataset is not publicly available but was shared directly with the authors by the data owner upon request.

A survey contains the answers of 642 companies affiliated with 44 clusters. The sample included clusters at various levels of maturity and development, excluding those in the early stages of development. The majority of the enterprises that responded to the survey were micro and small businesses, accounting for 38% and 32% of the sample, respectively. Medium-sized and large enterprises made up 18% and 12%, which is a considerably higher share compared to their presence in the overall business population in Poland.

The sample included enterprises from across all Polish regions, excluding only the Opolskie and Warmińsko-Mazurskie voivodeships, due to the absence of clusters meeting the inclusion criteria.

The employed primary data collection technique was CAWI [Computer Assisted Web Interviewing], facilitating online data collection from respondents.

The analysis is based on four main research questions:

1: Did the company use cluster assistance in digital transformation?

2: Did cluster participation contribute to an improvement in the utilisation of Industry 4.0 technologies?

3: How does the company evaluate the cluster's actions in implementing Industry 4.0 technologies?

4: Will the implementation of Industry 4.0 technologies be significant in the future?

Subsequently, an attempt was made to identify typologies of cluster members using cluster analysis, grouping similar responses to differentiate various types

of cluster members based on their attitudes and experiences related to digital transformation and Industry 4.0 technologies. The analysis was based on four key dimensions, each represented by different survey questions:

Exploitation: Usage of cluster assistance.

Effectiveness: Improvement in Industry 4.0 technologies due to cluster assistance.

Evaluation: Members' assessment of the cluster's activities.

Expectations: Future significance of Industry 4.0 technologies.

Responses were grouped based on the four dimensions. Each dimension had multiple response categories, which were quantified. Data analysis was performed with R, an open-source software for statistical computing and graphics.

4. Results of the research

In the area of Industry 4.0, the best results in terms of the median score were achieved by clusters functioning for a longer period, having the status of NKC, very large and having a written strategy, which is subject to updating. Considering the geographical area of cluster operations, the best score was achieved by the northern macroregion, which may result from the industry characteristics of the clusters located in this area; as well as in the southern region, which in turn is due to the presence of large and very large clusters with a high overall level of development. On the industry side, not surprisingly, the highest score was obtained by clusters from the ICT industry.

It is worthy of note that among the members of the clusters participating in the benchmarking, the share of organisations with DIH, EDIH or EDIH candidate status was relatively small (6 clusters with confirmed participation out of 41 participating in this survey).

Yet, it should also be stressed that the analysis of the strengths and weaknesses of the studied clusters divided into benchmark sub-areas (median value) revealed that cluster digitalisation has been indeed considered a strength (0.71).

The responses from all 41 cluster coordinators point out that, in terms of digitisation, IT systems for customer relationship management (80%), resource management (68%) and document management (66%) were most often used. Among the 13 identified Industry 4.0 technologies, widely understood IT systems (80%), cybersecurity solutions (73%), 3D production (71%) and cloud computing (68%) are the most utilised. Moderately used are big data analytics (61%), digital platforms (59%), Internet of Things (56%), autonomous robots (54%) and Industrial Internet of Things (51%). Less than half of the clusters use the following technologies: simulation (49%), artificial intelligence (41%), blockchain (37%) and artificial intelligence of things (29%). A significant increase in the use of artificial intelligence-based technologies can be forecast, due to, among other things, the current developments including GPT chat (OpenAI).

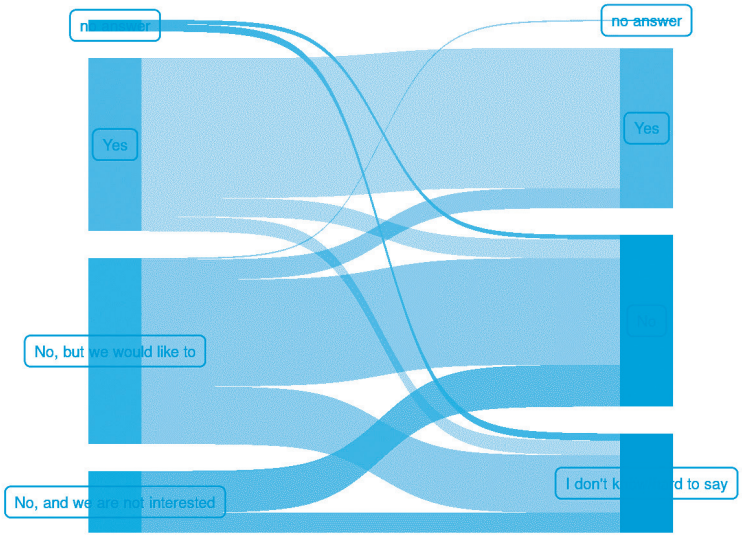
The authors begin this inquiry with a brief analysis of the key findings as provided in the Benchmark 2023 based on responses from 642 enterprises. The survey results pertain to companies' experiences and perspectives on cluster support in digital transformation, specifically regarding Industry 4.0 technologies. 33.4% of companies have utilised cluster support for digital transformation. A majority, 49.8%, have not yet used cluster support but they are interested in doing so in the future, while 13.4% have not and do not wish to seek such support in the future.

A large group of respondents (31.3%) affirm that cluster participation has improved their use of Industry 4.0 technologies. However, 39.5% do not believe there has been an improvement, and 29.1% are unsure or find it difficult to say (Figure 1).

Cluster members who received assistance in digital transformation experienced an improvement in their utilsation of Industry 4.0 technologies compared to those who did not receive such assistance. This is a finding that may indicate a positive impact of digital transformation support initiatives on the adoption and effective utilisation of Industry 4.0 technologies by cluster members.

FIGURE 1

Exploitation and Effectiveness – results of statistical analyses conducted using R software



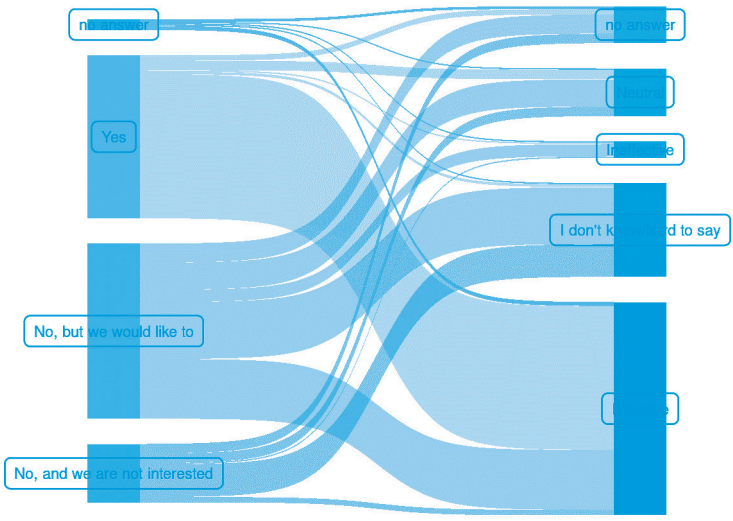
Source: own elaboration based on PAED data.

Then cluster members were asked whether the cluster participation contributed to an improvement in the utilisation of Industry 4.0 technologies (Figure 2). The cluster coordinators' efforts in facilitating Industry 4.0 technology implementation received a high rating from 44.9% of respondents. Those who did not use the cluster's assistance in digital transformation and implementation of I4.0 technologies yet, but would like to, tended to evaluate the cluster's assistance as neutral (14.2%) or unsure how to evaluate the coordinator's actions (37.2%).

The cluster members who received cluster assistance generally have a positive evaluation of the cluster in promoting and supporting digital transformation. This indicates the potential positive influence of cluster support on members' perceptions regarding the coordinator's effectiveness in promoting and supporting digital transformation.

FIGURE 2

Exploitation and Evaluation – results of statistical analyses conducted using R software



Source: own elaboration based on PAED data.

The last graph depicts the opinions of cluster members on the importance of Industry 4.0 technology in the 2-year perspective (Figure 3). A significant majority, 57.2%, believe that implementing Industry 4.0 technologies will be important in the future. However, there is still a group of cluster members (15.1%) not having an opinion on this issue or claiming that the implementation of Industry 4.0 technologies will be neutral for their activity in the 2-year perspective (16%).

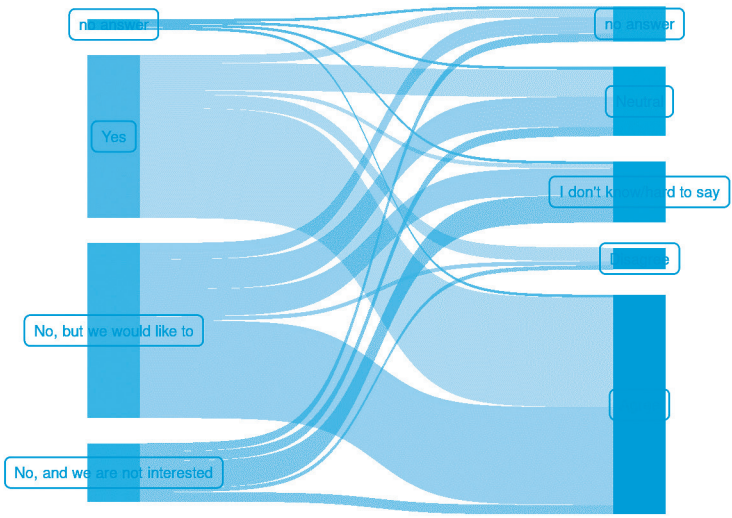
The distribution can provide valuable insights for cluster managers regarding which member groups are the most active or engaged in cluster initiatives and what needs or expectations they may have in the context of digital transformation and Industry 4.0 technologies.

The survey indicates a generally positive view of clusters in supporting the adoption of Industry 4.0 technologies, with many companies seeing the po-

tential benefits and expressing interest in leveraging such support in the future. Additionally, there is a strong belief among the companies surveyed that Industry 4.0 technologies will play a critical role in the future.

FIGURE 3

Exploitation and Expectations – results of statistical analyses conducted using R software



Did the company utilize cluster assistance in digital transformation and implementation of I4.0 technologies?

Will the implementation of Industry 4.0 technology be significant in the next 2 years?

Source: own elaboration based on PAED data.

5. Discussion/limitation and future research

To establish a typology of cluster members in the context of the provided assistance = and of the successful implementation of I4.0, the authors focus this analysis on the four dimensions – Exploitation of cluster assistance towards I4.0; its Effectiveness, Evaluation and Expectations among cluster members. Thus, authors try to diagnose the most prevalent profile/dominant group in each possible combination of cluster assistance and its impact, assessment, and the foreseen role.

TABLE 1

Exploitation of cluster assistance towards I4.0 – its Effectiveness, Evaluation and Expectations among cluster members [4xE]

		EFFECTIVENESS [improvement in I4.0]		EVALUATION of cluster's activities		EXPECTATION	
		Beneficiary	Unaffected	Satisfied	Dissatisfied	Convinced	Sceptical
EXPLOITATION [usage of clusters assistance]	User	166	49	**179 Happy Users**	3	164	13
	Nonuser	26	**221 Passive Observers**	106	20	**197 Procrasti-nating Adopters**	21

Source: the authors' work based on PAED data.

On this basis, in the subsequent phase of the study, an attempt was made to identify typologies of cluster members.

The first classification takes into account the utilisation of cluster assistance by cluster members and its effectiveness. The dominant group in this category can be labelled as: Passive Observers – members who do not use the cluster's assistance and are either indifferent or unaware of its potential benefits. Comprising 221 members who are unaffected and not using the assistance, this group may reflect a lack of awareness or the perceived relevance of the cluster's offerings, which suggests a target for increased marketing and education efforts. These cluster members take advantage of available assistance which seemingly translates into improved performance with respect to I4.0 technologies.

The second classification draws on the utilisation of cluster assistance and the evaluation of such help expressed by cluster members. The largest group in this respect [44.9]% evaluated the help positively. This group can be labelled as Happy Users – 179 evaluating the clusters's actions as effective. For 37% of

the respondents, it was difficult to assess the obtained help, while 3.7% were dissatisfied with the cluster's assistance.

The last combination contrasts the utilisation of cluster assistance with the expectations concerning the future importance of I4.0 in the next 2 years. The dominant cohort in this context (197 cluster members) can be named as Procrastinating Adopters – members who have not yet utilised cluster assistance but are interested in doing so, showing a proactive attitude toward adopting I4.0 technologies. The group reported not using the cluster's assistance but they are convinced that I4.0 technologies will be important in the future. Their high potential for future engagement and possible conversion into active users make them a critical focus for outreach and education initiatives.

Non-use of cluster assistance in digital transformation may be due to both insufficient knowledge of the availability of this assistance and a lack of conviction about the relevance of using this assistance. In other words, not using the assistance may be an expression of unawareness of the cluster offer or scepticism about the effectiveness of this assistance.

Fortunately, in the case of future expectations regarding the relevance of digital transformation and support policies in this area, cluster members consider this area as significant, which would suggest that Polish companies would like to base their competitiveness on innovations and advanced technologies, abandoning the reliance on low production costs or flexibility of the offer. Such attitudes require, above all, the provision of appropriately tailored and accessible knowledge regarding the digital transformation taking place and the assistance available from clusters in this area.

In addition to the availability of knowledge about the assistance on offer, the opinions of those who have already benefited from this assistance should also be decisive. Their positive evaluations and satisfaction with the received support, as well as the positive impact and improvement in business performance, should be the crowning evidence of the validity of using cluster assistance in digital transformation processes.

This study can in fact add a new dimension to the extant literature linking the digital transformation with clusters. It complements and confirms available studies which attribute clusters with special role of digital transformation accelerators or facilitators [Russo et al. [2022], Hervas-Oliver et al. [2020] at the same time stressing the need of closer inspection of the exact reception of this role. The nature of survey applied (Benchmarking) does not allow us to examine the precise tasks performed by cluster managers in advancing the I4.0 as established in the previous research [Jankowska [2021]; Dyba, Di Maria, and Chiarvesio [2022]. Nevertheless, this study and the obtained findings can be seen as an attempt to fill the existing specific empirical gap regarding the function of cluster organisation in ushering I4.0 as perceived by the cluster members. Thus, it can offer a unique perspective on the utility and adequacy of cluster organisations as vehicles and ecosystems facilitating I4.0.

Industry 4.0 within Polish clusters, revealing several important insights into cluster assistance and its impact on technology adoption. However, this study is not without limitations. First and foremost, it focused exclusively on Polish clusters registered with and participating in the Benchmarking study, potentially limiting the generalisability of the results. Expanding future research to include informal clusters or those in other countries would help shed further light on the broader trends in cluster support for digital transformation. Such comparative analyses across different regions or nations could better inform policymakers and cluster managers of how distinct environments and economic conditions influence cluster performance in digital transformation efforts.

Moreover, the data gathered in this study offers relatively basic insights regarding the support for implementing Industry 4.0 technologies. Future research should strive to capture more nuanced aspects of this assistance, including the specific methods and tools used to foster digital transformation, as well as the varied outcomes achieved by cluster members. This would provide a richer understanding of the mechanisms through which cluster assistance promotes technology adoption. Additionally, future studies could delve into the varying effectiveness of cluster assistance depending on the characteristics

of cluster members, such as whether they are small or large firms, domestic or international entities, or which sectors they belong to. Such distinctions are likely to influence both the type of assistance needed and its eventual impact.

Finally, while this study offers insights into the effectiveness of cluster assistance, more targeted investigations into the exact needs of cluster members are essential. Tailored support, designed around the evidence-based requirements of individual members, will likely lead to a greater impact than the broad, ill-targeted assistance. A more systematic approach to monitoring and evaluating the quality of cluster interventions would further enhance the effectiveness of cluster policies, providing valuable input for both practitioners and researchers alike.

5. Conclusions

In conclusion, this study contributes to the growing body of literature on cluster support for digital transformation and for the adoption of Industry 4.0 technologies. By examining Polish clusters and their efforts to facilitate technological advancement, the research sheds light on the relationship between cluster assistance and the enhancement of competitiveness among cluster members. The findings emphasise that clusters with more advanced digital capabilities can play a pivotal role in assisting less advanced clusters, thereby enabling broader dissemination of critical technological knowledge and skills.

The results highlight the positive perceptions of cluster members regarding the importance of digital transformation and the future role of Industry 4.0. This optimistic outlook presents a significant opportunity for growth and innovation, provided that cluster organisations can address current shortcomings and offer more targeted, effective assistance. The identification of dominant groups among cluster members, in relation to their engagement with cluster help, also underscores the importance of tailoring support to the varying needs and capacities of different companies.

While the study's focus on Polish clusters limits the scope of its findings, the research nonetheless offers valuable lessons for cluster coordinators and pol-

icymakers. The study's insights can guide the development of more effective, evidence-based cluster policies that align with the specific needs of members, ultimately driving greater technological adoption and competitiveness. The ongoing evolution of digital transformation within clusters requires continuous monitoring and research to adapt to emerging trends and ensure sustainable regional development in the future.

References

Baker P.M. A., Gaspard H., & Zhu J. A., 2021, *Industry 4.0/Digitalization and Networks of Innovation in the North American Regional Context*, "European Planning Studies", DOI: 10.1080/09654313.2021.1963053.

Balland P.-A., & BoschmaR., 2021, *Mapping the Potentials of Regions in Europe to Contribute to New Knowledge Production in Industry 4.0 Technologies*, "Regional Studies", DOI: 10.1080/00343404.2021.1900557

Benitez G.B., Ayala N.F., & Frank A.G., 2020, *Industry 4.0 Innovation Ecosystems: An Evolutionary Perspective on Value Co-creation*, "International Journal of Production Economics", no. 107735.

Buchi G., Cugno M., & Castagnoli R., 2018, *Levels ofOpenness to Industry 4.0 and Performance. An Empirical Analysis of Manufacturing Companies*, [in:]"Salerno University Proceedings", pp. 1–11, SALERNO UNIVERSITY GLOBAL ENTREPRENEURSHIP CONFERENCE "Social Innovation and Humane Entrepreneurship: From Policy to Action".

Capone F., Innocenti N., Baldetti F., & Zampi V., 2023, *Firm's openness and innovation in Industry 4.0.* "Competitiveness Review", vol. ahead-of-print, DOI: 10.1108/CR-07-2023-0178.

Castelo-Branco I., Cruz-Jesus F., & Oliveira T., 2019, *Assessing Industry 4.0 Readiness in Manufacturing: Evidence for the European Union*,"Computers in Industry", no. 107, pp. 22–32.

De Propris L., 2018, *Industry 4.0+ and Implications for European Regions. MAKERS'* Workshop, Brussels, https://www.ceps.eu/sites/default/files/Presentation%20Lisa%20DE%20PROPRIS%20Brussels%20January%202018.pdf [date of access: 25.01.2018].

De Propris L., & Bailey D., 2021, *Pathways of Regional Transformation and Industry 4.0.*, "Regional Studies", DOI: 10.1080/00343404.2021.1960962.

Fernandez-Escobedo R., Eguía-Peña B., & Aldaz-Odriozola L., 2023, *Economic Agglomeration in the Age of Industry 4.0: Developing a Digital Industrial Cluster as a New Policy Tool for the Digital World*, "Competitiveness Review", vol. ahead-of-print, DOI: 10.1108/CR-07-2022-0095.

Fiorini N., Pucci T., Casprini E., & Zanni L., 2023, *The Actors' Role in Industrial Districts Facing the Challenge of Technologies 4.0 between Absorption and Dissemination*, "European Planning Studies", vol. 31(7), pp. 1377–1396.

Fraske T., 2022, *Industry 4.0 and Its Geographies: A Systematic Literature Review and the Identification of New Research Avenues*, "Digital Geography and Society", vol. 3, p. 100031.

Gagnidze I., 2022, *Industry 4.0 and Industry 5.0: Can Clusters Deal with the Challenges? [A Systemic Approach]*, "Kybernetes", vol. 52(7), pp. 2270–2287.

Gillani F., Chatha, K. A., Jajja, M. S. S., & Farooq, S., 2020, *Implementation of Digital Manufacturing Technologies: Antecedents and Consequences*, "International Journal of Production Economics", vol. 229, p. 107748.

Götz M., 2021, *Clusters*, *Digital Transformation and Regional Development in Germany*, Routledge.

Hervas-Oliver J.-L., Gonzalez-Alcaide G., Rojas-Alvarado R., & Monto-Mompo S., 2020, *EmergingRegional Innovation Policies for Industry 4.0: Analyzing the Digital Innovation Hub Program in European Regions*, "Competitiveness Review", vol. 31(1), pp. 106–129.

Hervás-Oliver J.-L., 2022, *Industry 4.0 in Industrial District SMEs: Understanding Collective Knowledge Transfer by Research and Transfer Institutes*, "Competitiveness Review", vol. 32(5), pp. 647–666.

Hervás-Oliver J.-L., Di Maria E., & Bettiol M., 2021, *Industry 4.0 in Firms*, *Clusters and Regions: The New Digital Imperative*, "Competitiveness Review", vol. 31(1), pp. 1–11.

Hervás-Oliver J.-L., 2021, *Industry 4.0 in Industrial Districts: Regional Innovation Policy for the Toy Valley District in Spain*, "Regional Studies", DOI: 10.1080/00343404.2021.1939861.

Jankowska B., Di Maria E., & CyglerJ., 2021, *Do Clusters Matter for Foreign Subsidiaries in the Era of Industry 4.0? The Case of the Aviation Valley in Poland*, "European Research on Management and Business Economics", vol. 27(2), p. 100150.

McPhillips M., 2020, *Trouble in Paradise? Barriers to Open Innovation in Regional Clusters in the Era of the 4th Industrial Revolution*, "Journal of Open Innovation: Technology, Market, and Complexity", vol. 6(3), p. 84.

Ortt R., Stolwijk C., & Punter M., 2020, *Implementing Industry 4.0: Assessing the Current State*, "Journal of Manufacturing Technology Management", vol. 31(5), pp. 825–836.

Piotrowski M., Dziedzic K., Nowicki B., Lewandowska A., Macioch Ł., Sieradzki R., Marciniak-Piotrowska M., Thlon M., Krystowski K., & Thlon D., 2023, *Cluster Benchmarking in Poland – Edition 2022: General Report*, Polish Agency for Enterprise Development, Warszawa.

Pelle A., Sass M., & Tabajdi G., 2020, *European Integration and Industrial Actors' Location and Investment Decisions in the CEE Automotive Industry: What Types of Changes Are Likely to Be Brought by Industry 4.0?*, "Economia & Lavoro", vol. 54(1), pp. 31–44.

Pedro Guilherme Sanches Contieri R., Anholon & L.A. De Santa-Eulalia, 2021, *Industry 4.0 Enabling Technologies in Manufacturing: Implementation Priorities and Difficulties in an Emerging Country*, "Technology Analysis & Strategic Management", DOI: 10.1080/09537325.2021.1908536.

Sedita S.R., & Ozeki T., 2021, *Path Renewal Dynamics in the Kyoto Kimono Cluster: How to Revitalize Cultural Heritage through Digitalization*, "European Planning Studies", DOI: 10.1080/09654313.2021.1972938.

Trippl M., Fastenrath S., & Isaksen A., 2023, *Rethinking Regional Economic Resilience: Preconditions and Processes Shaping Transformative Resilience*, "European Urban and Regional Studies", DOI: 10.1177/09697764231172326.

Acknowledgements

This paper was enriched thanks to the Polish Agency for Enterprise Development – the owner of the database resulting from a survey with cluster members which was used for the analysis.

The contribution of the authors

Conceptualisation, M.G. and M.M. literature review, M.G.; methodology, M.G. and M.M.; formal analysis, M.M; writing, M.G. and M.M.; conclusions and discussion, M.G. and M.M.

The authors have read and agreed to the published version of the manuscript.