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Cluster policy revisited in the digital age:
from awareness and ownership
to mission-oriented value creation.
The case of Hamburg clusters

Abstract

This paper explores the interrelations between cluster (geographic concentration of interconnected entities) and Industry 4.0 (I4.0, business digital transformation) and the resulting consequences for cluster policy. Drawing on the case of Hamburg clusters, literature review and experts' consultations, it aims to identify and formulate policy recommendations relevant to the cluster's functioning in the digital transformation age. Whereas clusters may indeed nurture the implementation of Industry 4.0, the reverse impact of I4.0 on clusters can be diagnosed. Policy implications resulting from this co-evolution are discussed and recommendations for how to harness clusters as tools for advancing I4.0 and to adjust cluster policy in digital time are formulated. Cluster policy revisited in the digital age should build upon raising awareness and ensuring ownership/legitimacy to enable mission-oriented joint value creation.

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

JEL Classification Codes: M0, R10, O3

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Rewizja polityki klastrowej w erze cyfrowej: od świadomości i własności do tworzenia wartości zorientowanej na misję. Przypadek klastrów w Hamburgu

Streszczenie

Niniejszy artykuł bada wzajemne relacje między klastrem (geograficzną koncentracją powiązanych podmiotów) a Przemysłem 4.0 (I4.0, cyfrową transformacją biznesu) oraz wynikające z tego konsekwencje dla polityki klastrowej. Na podstawie analizy klastrów w Hamburgu, przeglądu literatury oraz konsultacji z ekspertami, artykuł ma na celu zidentyfikowanie i sformułowanie zaleceń politycznych istotnych dla funkcjonowania klastrów w erze cyfrowej transformacji. Chociaż klastry mogą rzeczywiście wspierać wdrażanie Przemysłu 4.0, można również zdiagnozować odwrotny wpływ Przemysłu 4.0 na klastry. Omówiono implikacje polityczne wynikające z tej współewolucji oraz sformułowano zalecenia dotyczące wykorzystania klastrów jako narzędzi do promowania Przemysłu 4.0 i dostosowania polityki klastrowej do czasów cyfrowych. Polityka klastrowa, zrewidowana w erze cyfrowej, powinna opierać się na podnoszeniu świadomości i zapewnieniu poczucia odpowiedzialności/legitymacji, aby umożliwić wspólne tworzenie wartości ukierunkowanej na misję.

Słowa kluczowe: klastery, Niemcy, Przemysł 4.0, cyfrowa transformacja, polityka klastrowa

Kody klasyfikacji JEL: M0, R10, O3

Introduction and conceptual framework

Digital transformation, often called Industry 4.0 (I4.0) or the 4th industrial revolution, is reshaping socio-economic life and impacts the functioning of clusters, seen as geographic concentrations of interconnected entities (Porter, 2000) and hybrid forms of hierarchies and markets (Maskell & Lorenzen, 2003) characterised by cooptation, rendering these places attractive locations (Malmberg & Maskell, 1999; Czapiewska, 2021; Kuberska & Mackiewicz, 2022; Kowalski, 2020). Although digital transformation is being studied from various angles, the meso and spatial perspective remains a somewhat under-investigated topic (Bellandi & DePropris, 2021). The presented research explores the interrelations between cluster and I4.0 and in a natural context, and by drawing on the case of German I4.0 clusters, additional literature review and experts' consultations, it aims to identify and formulate policy recommendations relevant to cluster functioning in the digital transformation age.

Martinelli et al. (2021) see I4.0 as a bundle of heterogeneous but convergent technologies, which builds upon achievements of the previous digital revolution, although

with particular attention to, and relevance of, integration and interconnectivity. Industry 4.0 is the result of complex relations between technical and social aspects in the process of the digital transformation of production (Prodi et al., 2022). Policy instruments adopted at various levels of the system contribute to catalysing the sociotechnical changes underpinning Industry 4.0, with I.40 depicted as a significant disruption in current value creation, a reform if not a revolution of business models, or as a state-sponsored strategy of reindustrialisation and vision of modern industry (Strange & Zucchella, 2017, 2016, 2015; Liao et al., 2017; Kagermann et al., 2013; Ciffolilli & Muscio, 2018).

Firms operating in clusters – conceived as geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities achieving the benefits from agglomeration (Porter, 2000) – seem to be better equipped to face the fast-changing turbulent environment of Industry 4.0. Locally embedded knowledge accompanied by the strong presence of industry, and assisted by proper governance management, facilitates the implementation of I4.0. Available research (Bembenek, 2017; Götz & Jankowska, 2017) shows that the multiple advantages of clusters can facilitate the implementation of Industry 4.0 solutions, particularly thanks to such channels as: knowledge environment due to the interactive character of learning and the peculiarities of knowledge creation; an atmosphere of trust and mutual understanding, reducing uncertainty and helping risk sharing; the concept of a fractal and connected company, promising policy tool and favourable business ecosystem. The idiosyncrasies of Industry 4.0 also impact the functioning of clusters, as they require a more interdisciplinary and integrative approach (Busch et al., 2021; Götz & Jankowska, 2017). The previous research on clusters & I4.0 mutual relations stresses the digitally triggered evolution of clusters towards providers of industrial commons and hubs of related varieties (Götz, 2021).

The literature on cluster policy shows that it has its roots in a variety of policy fields – science and technology, innovation, industrial or regional policy (Sternberg et al., 2010), and can come in many forms and shapes (Hospers & Beugelsdijk, 2002; Szulc-Fischer, 2020; Lis, Kowalski, & Mackiewicz, 2021; Wiercioch, 2020; Citkowski, 2020). Policy interventions typically seek to address market failures and system failures, such as infrastructure, institutions or network issues. Although cluster policy can be perceived as one of the most relevant instruments in the domain of science, technology and innovation policy, it continues to vary greatly in terms of the scope or goals (Blümel, 2021). Cluster policy is horizontal, combining industrial and innovation policy with labour market, professional and higher education policy. Grashof (2021) discussing the cluster policy points out the

need to distinguish between two basic types of interventions – the measures aiming at cluster emergence and the actions stimulating the efficiency of existing clusters. Abbasiharofteh (2020) distinguishes ‘cluster policy’ with a narrow focus that concentrates on the local authorities’ role, and ‘policies for clusters’ with a broader focus that defines clusters as complex systems with actors embedded in various networks. Abbasiharofteh (2020) further differentiates between two types of interventionist approaches. The first one aims at intensifying network relations and relies on an exploitative approach, which prevents lock-out and cluster members’ exclusion. The second type – called restructuring, epitomises an explorative approach oriented at preventing lock-in or inertia within knowledge networks. The goal of cluster policies goes beyond simply enhancing firms’ innovation and interactions among them (Mar & Massard, 2021), and targets structural effects of specific technologies pursued and links to other technologies intensified or newly created (Basilico et al., 2021). Not only can clusters facilitate transformation towards I4.0 thanks to their attributes, but there are also explicitly dedicated and top-down digitisation clusters called DIH (digital innovation hubs), which can epitomise the digitally-focused innovation policy (Hervas-Oliver et al., 2020). Although DIHs still seem to be at the trial-and-error stage, they are supposed to stimulate multi-actor collaboration aiming to transition into Industry 4.0 by facilitating the emergence of place-based alliances that account for regional contextual specificities and by promoting learning by interacting. As argued by Hervas-Oliver et al. (2020) policymakers should be aware that the DIH programme constitutes a template for launching regional digitisation initiatives, although it is still a one-size-fits-all policy that undoubtedly entails contextualisation and adaptation to local needs and different settings. As argued by Grashof (2021), policymakers are advised to generate initiatives adjusted to the specific firm, cluster and market/industry characteristics, rather than pursuing generic cluster policies. As suggested in a study of the Tuscan region by Fiorini et al. (2021), the development of I4.0 in industrial districts/clusters requires both absorption, i.e. an adequate level of adoption of new digital technologies along different dimensions within firms, as well as dissemination both internally within the company and externally within-cluster among its members. Sandulli et al. (2021) examined how regions design policies to facilitate their transition to Industry 4.0, with the results demonstrating that at the local level, I4.0 policies must accommodate and integrate multiple factors such as the position system in GVC, the power of the actors involved in the innovation system, the institutional structures shaping the exchange of I4.0 knowledge among agents, and the connection between the synthetic and the analytical knowledge base. A case study of the Basque Country and Catalonia demonstrates that it is not feasible to define a general policy of promot-

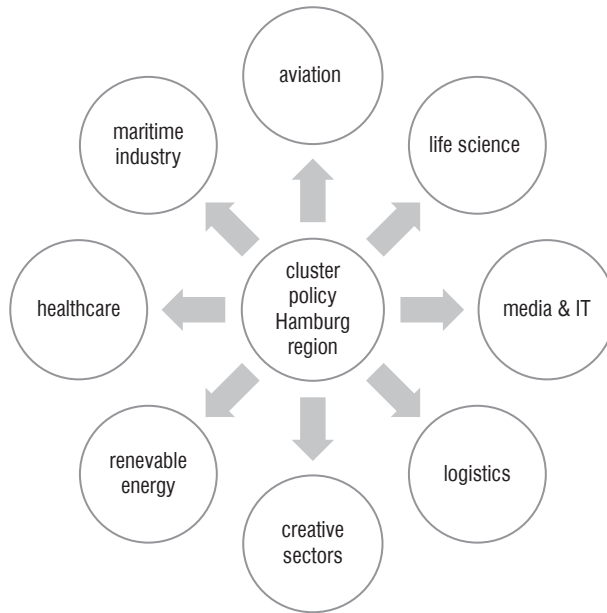
ing I4.0 suitable for all, and each region needs to individually design its I4.0 policy adopted to specific local characteristics, as a simple replication of policies from other regions is simply ineffective. Karlsen et al. (2022) by drawing on the qualitative case study of two Norwegian clusters, argue that the key for clusters and cluster members facing the disruptive I.40 related transformation is the active role played by Cluster Intermediaries (CI) in developing the adequate cluster absorptive capacities (CAC) defined as a capacity to absorb, diffuse and exploit extra-cluster knowledge. The CI function needs, however, to be sensitive to local context and must account for the type of knowledge base at hand, whether analytical or synthetic. Whereas the former suggests the need to develop education, human capital and skills, the latter implies investing in R&D facilities and external cooperation.

The extensive case study of Hamburg clusters allows for diagnosing the antecedents of the cluster's importance for business digital transformation and identifying the likely reverse impact. These findings, combined with a narrative literature review and experts' consultations, enable reflection upon ensuing policy challenges, hence allowing to formulate recommendations for how to harness clusters as tools for advancing I.40 and adjust cluster policy in digital time. This paper is normative and seeks to offer evidence-based guidelines, but it is not meant as a manual for cluster policymakers. Instead, it provides a set of aspects to be considered when designing and pursuing cluster policy in digital time.

Methodology – a qualitative study in Hamburg clusters

This research draws on the case study embedded in the qualitative approach (Karafyllia & Zucchella, 2017; Welch et al., 2011), which is instrumental in developing a context-based description of phenomena in areas where prior knowledge is scarce. A qualitative study based on gradual iterative collection and analysis of information was adopted to explore and generate explanations strengthened through empiricism (Glaser & Strauss, 1967; Strauss & Corbin, 1990; Charmaz, 2009; Eisenhardt, 1989; Yin, 2009). These research activities provide insight into the cluster's contribution to I4.0 advancement and into the impact the fourth industrial revolution has on clusters.

In addition to the literature review, this explorative study draws on the expertise gained during two field studies in the Hamburg Metropolitan Region, a renowned centre for successful cluster development proclaimed in 2004 as one of six European 'Model Demonstrator Region for modern cluster policy'. There are eight clusters in the Hansa Hamburg region (Scheme 1).

Figure 1. Hamburg clusters

Source: own elaboration based on www.hamburg.de/wirtschaft/clusterpolitik-model-region

Thus, this area, with its significant number of well-functioning, often globally renowned and internationally distinguished clusters (quality labelling system of the European Cluster Excellence Initiative), seems particularly well positioned to study the intricacies of cluster policy, to observe the evolution of such policy, and to diagnose the challenges faced in its design and implementation. The policy pursued in Hamburg towards clusters is committed to supporting inter-organisational cooperation among metropolitan clusters to foster regional competitiveness, with one of the key initiatives in this respect being the ‘Co-Learning Space for Hamburg’s clusters’ project launched for pooling knowledge flows among clusters and orchestrating their endeavours to the mutual benefits aimed at collective engagement with new topics and new stakeholders in the pursuit of the acquisition of new knowledge and technology transfer. Special attention in this study is paid to the Hamburg Aviation cluster HAV, which is a so called ‘excellence cluster’ combining both the bottom-up initiative and the metropolitan Hanseatic city – an agglomeration of firms and the functioning Cluster Organisation. The calculated location quotient (LQ) of 4.4 means that compared to the national average, 4.4 times as many people are employed in HAV in the aviation sector. It is one of 40 “I4.0 branded” clusters out of more than 400 recognised by Clusterplattform Deutschland (<https://www.clusterplattform.de>), and the world’s third-largest aviation hub after Seattle (Boeing) and

Toulouse (Airbus), plugged into the global network of mainly civil aerospace manufacturing via the anchor company Airbus. Interviews were conducted in Spring 2019 as guided conversations, and encompassed twenty-six persons – cluster representatives, cluster experts, cluster companies, cluster officials and cluster scholars (Götz, 2021). Additionally, in the supplementary follow-up research, in-depth interviews (incl. participatory observation) were conducted in Hamburg during an Erasmus+ research stay in March 2022. Interviews were conducted with Co-learning Space (CLS) managers (CLSm1,2,3), a Hamburg Ministry official (HHo), and Hamburg cluster representatives (HHcr1,2,3).²

The presented research on the case of the Hamburg clusters – the CLS initiative of all eight metropolitan clusters and HAv – may contribute to a timely discussion on the regional and policy aspects of the fourth industrial revolution. By providing insight into the geographic perspective of I4.0 and diagnosing interrelations between clusters and digital transformation, the research attempts to identify the features of modern cluster policy, and should complement the emerging literature in this respect, contributing to novel and promising research on the cluster's role in the digital age, and in particular the evolving nature of cluster policy.

Cluster nature and business digital transformation – Hamburg clusters and HAv

A cluster can be the right tool for advancing I4.0 if there is solid and high-quality research, accompanied by the demand for new solutions from the strong business and industry circles, and additionally assisted by the governance structures (Götz, 2021). The specific attributes of the fourth industrial revolution entail the need for a more interdisciplinary, integrative if not truly holistic approach drawing on ecosystems (Benitez et al., 2020). Besides manufacturing and technical capabilities, which stimulate innovativeness across industries, i.e. the industrial commons (IC – knowledge, competencies, skills, institutions, R&D, etc.), a cross-sectoral perspective incorporating a different know-how base and strands of engineering, i.e. related variety (RV – dynamic complementary externalities originating in similar industries; potential for diversification and deployment of similar resources) is desired (Pisano & Shih, 2012; Frenken, van Oort & Verburg 2007).

² I would like to also express my gratitude to the senior expert from TCI Network for valuable comments and remarks on this study. The quotations incorporated in the body of this text may not be always the exact verbatim expressions as transcribed, as in the case of both the interviewers and interviewed the interviews were conducted not in their native languages, hence they reflect the interpretation and main message conveyed, although not necessarily word for word.

A pilot study of the HAv cluster revealed that the industrial commons offered by a cluster should consider future competencies, skills and knowledge, and should be as common as possible, i.e. apply to all members of the cluster, while their development should take place through multi-level communication. Time is a dimension that strongly influences IC in the cluster and refers to actively looking ahead to identify and develop critical competencies for the cluster early on, although it also relates to the consequences of previous events, including the breakdown of the local industrial fabric due to specific processes. The RV is visible, among others, in the profile of a dominant part of companies, whose portfolio combines various activities balancing between “specialisation in diversification” and “diversification within the specialisation”. Such an arrangement allows new areas of activity and new branches to emerge (branching), e.g. the development of urban air mobility or unmanned aerial vehicles.

The processes of sectoral expansion are part of developing complementary competencies, which are vital for maintaining a competitive advantage of cluster companies, de facto determining their sustainable growth. Geographical expansion occurs on many levels, but its success requires the bottom-up involvement of cluster members to ensure its sustainability. Hubbing in Hamburg clusters, in particular HAv, means opening the cluster to the outside world thanks to hosting members from outside the metropolitan region; via the Airbus Toulouse/cooperation networks, thanks to activities of the European Aerospace Cluster Partnership or strategic links with selected foreign clusters. Blending is also actively supported by combining the bottom-up and top-down processes by cross-clustering, co-learning and bridging initiatives of the Hamburg metropolitan region.

Clusters can play an essential role in digital transformation and are predestined to be the leading managers of this process, as they have a broader perspective that includes all cluster members, thus being part of a holistic approach to Industry 4.0. It is also worth highlighting the disruptive nature of many digital solutions making joint coordinated action and multi-actor compliance necessary.

Clusters facing digital transformation – searching for policy implications

Whereas there is no consensus regarding the precise definition of I4.0, there is a general agreement that it represents a technological paradigm shift with multiple uncertain consequences. According to a senior expert from TCI Network, “Digitalisation is undoubtedly on the agenda; clusters need to tap into the opportunities pre-

sented by digitalisation. Even if digital transformation may be not at the core of cluster policy, it is becoming more and more integrated into cluster management, acknowledged as a strategic priority area". Also, in Hamburg clusters, there are opinions that **(HHcr1)** "digitalisation affects clusters, but like decarbonisation or demography, it is among the trends visible in a cluster's everyday life". Nevertheless, **(HHcr3)** "the impact of I.40 on cluster policy would not be so radical, rather linear, green transformation seems to be more disruptive, all the hydrogen hype".

The prospects of improved productivity, sustainability, more social inclusion, and prosperity can be compelling. However, they can materialise only on the condition of an appropriate industrial ecosystem and accompanying supportive policy regime. According to Hamburg clusters, **(HHcr1)** "clusters offer advice, coordinate the insight from academia, public spheres, public opinion and industry, and hence create ownership of these activities, and build and assure legitimacy for new I.40 solutions." **(CLSm3)** "Cluster's make the final outcome legitimate so that it reflects the needs of all stakeholders."

Balland and Boschma (2021) argue that any policy intervention that aims to develop I4.0 related technologies must take the potential that the region possesses as a point of departure in this kind of technology. According to them, "regions with a low or no I4.0 potential should think twice before investing public funds in such technologies, because the risk of policy failure is high". Thus, public policy should focus on regions that already possess I4.0 related capabilities, which constitute assets that make the policy effective. Developing the strengths in Industry 4.0 is not simply about the emergence of new technologies, but about the parallel capacity to adopt and adapt them. In Hamburg, for instance **(HHcr1)**, "basically, it is first about networking; inviting new participants; secondly – information and advice provision; thirdly – inspiration – spotting challenges and seeking solutions, and fourthly – offering value-added and making impact." According to Balland and Boschma (2021), the ambitious policy goal to reduce technological disparities among EU regions seems endangered if not all of them have integrated I4.0 technologies and local capacities to adapt to the disruptive nature of Industry 4.0. This is also recognised in Hamburg. **(HHcr2)** "When you think about the transformation from analogue to digital you should account for two things – financing and needs. Firstly, clusters can more easily apply for funds and accompany firms in their digital transformation. Secondly, they know about the member's needs, can transfer necessary information, connect interested parties, and also assure a level playing field in case of asymmetry."

Labory and Bianchi (2021) stress that regions need to create dynamic capabilities if they wish to adapt to big disruptions such as I4.0 successfully. This view is shared also in Hamburg. **(HHcr3)** "Clusters bring together members, then raise awareness and

generate more public relationships, so they shape the digital implementation by accounting for all stakeholders (...) clusters have the qualities to accelerate this transformation.”

By analysing the ceramic cluster in Castellon, Hervás-Oliver et al. (2019) diagnosed the role of place-based policies necessary for the digitalisation of the industrial district. Thanks to the bottom-up actions of local institutions and the support of policies at the regional level, cluster firms managed to overcome their inertia and limited knowledge concerning the opportunities of investments related to Industry 4.0 technologies. The case of the Toy Valley district in the Valencia region of Spain clearly shows how collective action helps diffuse Industry 4.0 (Hervás-Oliver, 2021). I4.0 has been implemented through initiatives that bypass many barriers thanks to utilising a collective project built upon cooperation. Such an approach can be also found in Hamburg clusters. **(CLSm1)** “Collaborative initiatives aiming at bypassing barriers define the cluster role in advancing digital transformation. Various ways of orchestrating activities and providing public goods are practised – like the world coffee format for discussing AI.” Further to this, **(HHcr1)** “you need to adequately communicate and sell these innovative projects in social media in order to get wider support”. The case of the Hamburg clusters also implies that clusters seem to emerge as the right agents for handling complex (digital transformation) projects, where multiple variables must be included and multicriteria optimisation is necessary.

A comprehensive study by Ciffolilli and Muscio (2018) revealed that the policy task relies not simply on safeguarding favourable conditions so that local capacities necessary for I4.0 technologies would be provided, but rather on stimulating joint initiatives where regions could diagnose their unique specialisations and spot complementarities in the know-how and skills required to adopt I4.0 technologies. As the case of the Hamburg clusters, in particular HAv, shows, and the practice of smart specialisation suggests, the diversity of the cluster profile should be nurtured, i.e. policymakers need to facilitate both specialisation and diversification, and foster intra-regional cross-sectoral cooperation by offering bridges (Fromhold-Eisebith, 2017). Creating a so-called cluster space (fairs, exhibitions, workshops) that enable cross-fertilisation and co-learning is important given digital transformation’s disruptive yet interdisciplinary nature.

Fromhold-Eisebith et al. (2021) agree that I.40, as a new paradigm with digital tools allowing coordination of value chain interactions, will considerably enhance product quality or process efficiency contributing to international competitiveness. Even if it raises high hopes among policymakers, it is often ambivalently viewed by industry actors themselves, and proper recognition of cluster members’ perceptions and attitudes seems an inevitable prerequisite for effective cluster policy in digital time.

A study on European IoT clusters (Remotti et al., 2019) showed that they perform a set of overarching activities and provide various services to their members. Specific policy interventions should encompass the identification of emerging risks; harmonised framework to address standards, counselling on IP law, privacy and personal data protection and data ownership, creation of labs, testing facilities; development of platforms cutting across sectors and promotion of international dialogue. Policymakers need to bear in mind the “professionalisation” of cluster management if they wish to fully grasp the benefits of their policy. This opinion is also shared in the Hamburg clusters (**CLSm3**): “we recognise the need to improve the quality of cluster management. We are supposed to help raise funds, and apply for external financing, which is intensively sought after, particularly for innovative risky initiatives.”

Cluster policy must account for interactions at multiple levels. The relevance of multi-scalarity in regional transformation is recognised in recent literature on economic geography and regional studies (Benner, 2021), and seems further enhanced by the digital affordances provided by I.40. Hamburg cluster representatives also agree that digital transformation (**HHcr3**) “will result in more geographical expansion, but this should be guided by the actual needs. Currently, the problems are bigger in the sense that they require insight from different actors, and often you cannot find answers locally, but you need to turn for help outside the cluster; confronted with questions that span your competencies you seek support outside your cluster”. Given the territorial constraints of I.40 as argued by Bilbao-Ubillos et al. (2020) public policy intervention must both buttress local conditions of excellence and work towards improved quality of the connections between the local and the global centres.

The specificity of a given sector that a cluster represents must be considered, but the universal nature of I.40 technology (GPT or key enabling technologies) can act as a modulator of diversification and opening to the outside world. Cluster policy needs to acknowledge that this openness takes place at different scales and implies metropolitan sprawl, national stretching, and more formal and coordinated European and global coupling.

The field study findings point out the importance of collaboration and competition, and the role of cluster organisation as a coordinator. Indeed, advances in digitalisation and the rise of I.40 with more interconnectedness and interdependence of technologies and business organisations make coordination more relevant than before. Micek et al. (2022) showed that the development of a regional path in Silesia towards Industry 4.0 would not have been possible without related variety, existing regional assets, knowledge flows from outside and the new policy instruments emphasising joint coalition built by various stakeholders.

The future orientation on developing competitive advantages, including generating skills and competencies of future generations, must feature high on the cluster policy agenda. A recent study by Bailey and De Propriis (2020) confirmed the importance of developing new skills and the ongoing reskilling and upskilling processes. This is also recognised in Hamburg clusters (**HHcr1**) “developing skills, providing vocational training, sensing future labour market needs, or requalification challenges, all are pressing tasks for clusters in digital time”. Challenges for cluster policy arising from digital transformation are indeed numerous (Scheme 2).

Scheme 2. Industry 4.0 induced changes in cluster policy

Policy implications resulting from the **cluster-I4.0** co-evolution

“Awareness and ownership/legitimacy”

Rising **awareness**, **breaking barriers**, and building bridges for cooperation, assuring **joint development**, public opinion understanding and hence **ownership** of activities – jointly **sensing**, **shaping** and developing future **skills** and key competencies

“Sustainable competitive advantage”

Cross-bridging and **co-learning** activities fostering diversity to develop complementarities and moving **beyond own core** competencies.

“Perspective levels”

Digital transformation as a **complementary tool** facilitating cluster policy makers activities and the **conceptual topic** being handled, a **challenge** to deal with, and also dependent on **company-level** needs.

“Sustainability”

Sectoral and scale expansion stimulated to enhance the **core competitive** advantages; processes of cluster stretching should be harnessed for **upgrading** the key cluster competencies.

“Mission-oriented value creation”

Digital transformation as a **catalyst** further **redefining** clusters’ role as **agents** for tackling grand societal **challenges**.

Source: own elaboration based on the literature and Hamburg clusters.

An extensive European study on IoT clusters (Remotti et al., 2019) revealed that government bodies are critical contributors to territorial clusters, but not to their sustainability and to sustain cluster missions. Clusters are successful only if they can create value for their stakeholders and appropriately adjust strategy and operations. Moretti (2013) confirms that “clusters can’t afford to cling to a declining industry but need to leverage their unique strengths to reinvent themselves before the tipping point is reached and the local ecosystem enters a downward spiral”. Hamburg clusters representatives argue that (**CLSm1**) “In digital time, cluster policymakers need to broaden their offer, extend their assistance, and be better and more competitive.”

The evolution of cluster policies implies (Grashof, 2021) moving from one-size-fits-all interventions through an off-the-shelf approach (focus on selected regions, industries, or firms) to tailor-made policies. This fine-grained more granular approach, which addresses concrete problems such as diversity, matching, connectivity and networking or resources and capability issues, emerges also out of Hamburg clusters, particularly the HAv study. **(CLSm1)** “Clusters can contribute to the development of digital transformation by breaking down barriers and applying various formats of cooperation according to logic forms follows function. On the other hand, digital technologies assist clusters in their activities rather than causing redundancy. Nevertheless, cluster policy must make effective use of these tools and outcompete non-cluster applications.”

One should be aware of ambivalent assessments regarding current cluster policy; on the one hand, assuming an exact, surgical approach targeting a specific aspect of cluster existence, on the other hand promoting the creation of a broader horizontal ecosystem (Hassink & Fornahl, 2017). Also, in Hamburg clusters, voices on the specificity of cluster policy and inward versus outward orientation seem to be split. Whereas some claim that it is more critical to first buttress local conditions of excellence, others argue to work towards improved quality of the connections between the local and the global centres. Some believe that an adequate approach requires the creation of a broader horizontal ecosystem, while others prefer a more surgical approach targeting a specific aspect of cluster challenges. **(CLSm1)** “It is more important to open and connect to the outside world when it comes to fostering digital transformation in clusters.” **(HHo)** “Clusters should be aware of not too much defocusing, specialising is the basics, likewise geographical proximity, and mastering local excellence should come before seeking connections to the outside world.” **(HHcr3)** “I would say that targeted actions may prove to be a better solution, so I think it is more relevant to tackle individual needs”.

As argued by Bellandi and DePropris (2021), the transition of local production systems (clusters) to an I4.0+ model would proceed along different paths, depending on their industrial history, nature of embeddedness and overall dynamics. To be successful, such transitions require local stakeholders – policymakers and business representatives, to co-shape this wider change, while bearing in mind the unique needs of the place, features of its transition path, and nesting in the national system, all of which imply a substantial investment, proper time horizon, and careful considerations of the possible externalities and trade-offs. Grashof (2021) speaks figuratively about abandoning the watering can and shifting towards a more targeted and problem-oriented approach that factors in the heterogeneity within the cluster context.

The role of local communication according to the principle that communication shapes an organisation has to be recognised and adequately addressed. The relevance of cluster branding, jointly shared identity and sense of belonging must not be underestimated, particularly in the face of challenges induced by digital transformation. Sosnovskikh and Cronin (2021) demonstrated that underappreciated elements, such as culture, attitudes and perceptions or governmental characteristics, have a significant influence on the effective development of industrial cluster policies. As stressed by Sternberg (2021), policymakers aiming at supporting digital regional entrepreneurship must, though, mind the gap and patiently implement a certain solution that should be evidence-based, i.e. they need to back not the desired but the already existing entrepreneurial ecosystems. Mar and Massard (2021), drawing on the French case, indicated that cluster policy should not ignore or belittle the relevance of simple animation actions or common services, both as an independent instrument and as an effective complement to subsidies for R&D projects.

Cluster policy should acknowledge the importance of coopetition, i.e. simultaneous cooperation and rivalry among cluster members. The field study findings point out the importance of collaboration, competition, and the role of cluster organisation as coordinator. Indeed, advances in digitalisation and the rise of I4.0, with more interconnectedness and interdependence of technologies and business organisations, make coordination more relevant than before. This brief review is not meant as a manual for cluster policymakers, but provides a set of aspects to be considered when designing and pursuing cluster policy in digital time.

Conclusions

This research can add to the emerging literature on the interdependencies of the ongoing business digital transformation and clusters. Previous studies revealed that clusters might be the right policy tool for implementing the digital transition, as they seem to offer a conducive environment in this respect thanks to the offered advantages, and even if, under the pressure of the fourth industrial revolution, the nature of clusters would be modified, they seem to remain an attractive platform for digital business transformation. A senior expert of TCI Network argues that “In terms of cluster policymaking, it seems that rising awareness is becoming critical; all in all, cluster policy in digitalisation is first and foremost about assisting cluster members in mapping their needs, and is primarily about having the right mindset and promoting it among members, thanks to proactive actions and building trust.”

Conducted research helps qualitatively verify the results of the previous study, which states that clusters in the digital age would be expected to provide the industrial commons and related variety. Hence, the research allows us to evaluate the importance of these two concepts as factors defining a cluster's attractiveness for developing I4.0, additionally enabling assessment of the nature of stretching processes that the cluster undergoes. The identified modifications bear consequences for policymaking, with some implications resulting from the cluster-I4.0 co-evolution identifiable. The need to jointly develop future skills and competencies, along with bridging activities fostering diversity to nurture complementarity, should be highlighted, and cluster stretching should be harnessed for upgrading the core competences of the cluster. These findings seem to be aligned with claims by Lund and Vildåsen (2022), who showed how global expectations created by the Industry 4.0 narrative trickled down into national industry and innovation policies, and hence how such discourse could be anchored locally by agents in their agendas, which are then manifested in daily operations in the region.

Policy implications resulting from the cluster-I4.0 co-evolution illuminate the need for a joint focus by all cluster actors on developing sustainable competitive advantages. The presented considerations seem to be aligned with recent calls for an industrial policy, which in the I4.0 age (Bianchi et al., 2019) should be place-based and integrated, work at the intersection of technology and territory, provide public goods characterised by multi-disciplinarity, ascertain openness, facilitate a network business culture, and prevent exclusion and polarisation.

Promoting the provision of industrial commons and safeguarding the related variety development along with smart modelling of cluster stretching processes might be seen as the new transformative place-based policy. Such policy needs to 'connect' technologies, sectors, and places so that it recognises real chances of transformation pathways as it accounts for local innovation, docking and translational capabilities (De Propris & Bailey, 2021). New studies quoted by Gong et al. (2022) show that companies, the state, or academia, when advocating the need for transformation, must adopt their narratives and 'run in packs' to allow emerging industries to establish. Such activities provide necessary legitimacy and create ownership of ongoing transformation processes. The expected revision of clusters' roles is shared by experts – "future-oriented thinking needs to guide and define the cluster policy. It is less about how narrow, precise, or how far-reaching this policy is, but rather about the mission". Similar views are shared among the Hamburg clusters. **(CLSm2)** "Clusters in the future should be about the mission". **(HHcr3)** "It is less about technologies but more about solving societal needs, like with the green turn. You need

to focus on a solution, on impact, hence the cluster's role is now redefined towards solving societal problems rather than adopting any technologies."

Adaptability and the reinvention of clusters should be the motto for the future in the disruptive era of I4.0. Policy support should focus on cluster changes, integration of new knowledge, a fusion of sectors and technologies, and the emergence of new industries. It needs to account for embeddedness in the regional context, yet safeguard openness; and be geared towards expansion while acknowledging the stages of development.

These obtained findings signify the ongoing change in the attitude and behaviour of cluster shareholders. The opinions gathered from cluster organisations' representatives, as well as experts and company managers, demonstrates the revision of challenges faced in digital times, the pervasiveness and complexity of issues related to digital business transformation, and thus the need for a certain redefinition of the cluster mission and reorientation of how the cluster policy should be perceived and designed.

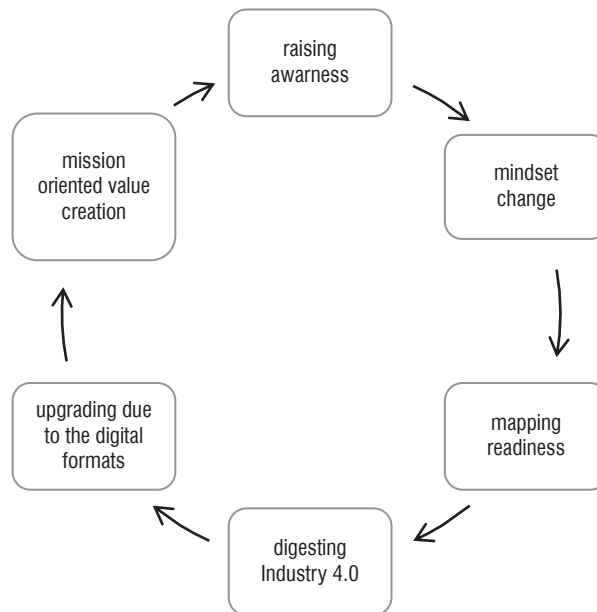
Policymakers must adopt the dynamic approach and design and pursue a policy that accounts for the cluster evolution, where the latter is further modulated by the ongoing digital transformation, resulting in some form of co-evolutionary pattern. Due to the cluster's evolution and passing through successive stages of development, there is a need for clusters to open to the outside. This should be seen in terms of defensive action, protecting against isomorphism, but also as an offensive attempt, allowing competitiveness to be strengthened (Bellusi & Hervas-Oliver, 2016). However, the evolution that clusters undergo should be understood not as a pre-determined path-dependent life cycle, but rather as complex transformation. In the light of I.40 properties, clusters should more and more be seen as agglomerations of competencies and skills, rather than from a strictly sectoral perspective (Pisano & Bucci, 2017). Despite the universal nature of I.40 solutions (GPT general-purpose technologies), cluster policies need to be very context-sensitive (Trippel et al., 2016), accommodate diversified needs and adjust to local unique requirements.

This study is not without limitations and suffers the typical shortcomings of a qualitative study, but it can advance our knowledge with respect to the cluster policy in digital time. Further analysis could, for instance, refine the scope of examination by a more precise questionnaire and more nuanced scenarios of interviews. Additionally, future studies could also replicate the approach adopted and thus repeat this study to observe the likely evolution over time, and our cluster policy knowledge could also be enriched if the study were extended to cover and explore other regions or countries in Europe and beyond. Cluster policy might even further gain relevance with the development of quantum technologies, which would

disrupt industries, business models and value chains (Rapp, 2021). As this requires a tailor-made approach accounting for the peculiarities of different sectors, company profiles or business models, and needs a thorough and lengthy testing phase, the coordination and supervision provided in fully-fledged clusters should not be overestimated. Reaching market maturity of quantum technologies should be based on the quantum ecosystem that is engaging industrial companies, cooperation with research, and financial institutions all potentially available in functioning clusters.

As it seems, the cluster policy space in digital time features at multiple levels – local, regional, national or global. This also suggests that it needs to be assessed in terms of progress in learning and ongoing change. It is important to acknowledge that cluster policy during the digital revolution has a lifecycle, as do clusters themselves (Scheme 3).

Scheme 3. Proposition of a cluster policy cycle in the digital era



Source: own elaboration based on the conducted study.

The results suggest that clusters could contribute to digital transformation by raising awareness and creating key ‘ownership’ of processes for transformation. However, because of digital transformation, and as identified in this research, clusters would become agents for mission-oriented value creation. The concept of ownership as an important facilitator of digital transformation diagnosed in this study and provided by cluster policies can be linked to legitimacy, which plays a central

role in emerging industries (Gong et al., 2022). Thus, it could be argued that cluster policy would evolve towards being a catalyst for new industries to emerge, and an instrument facilitating the formation of new industries.

Author Contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of Interest

The author declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics Statement

The author certifies that the research published in the text was carried out in accordance with the research ethics of the affiliated university.

Research Data Availability Statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

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