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Do clusters matter for foreign subsidiaries in the Era of industry 4.0? The case of the aviation valley in Poland

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ABSTRACT

Many scholars underline the significance of clusters for knowledge spillovers and related benefits in terms of innovation and firm competitiveness. The Industry 4.0 technological scenario emphasizes dispersed technologically interconnected activities and distributed knowledge management opportunities, while clusters focus on proximity, which is why many question the attractiveness of the latter for firms. Bearing in mind the scarcity of studies on the relationship between digitalization and clusters, the paper discusses how clusters may be attractive for foreign subsidiaries in times of the fourth industrial revolution by referring to the case of the Aviation Valley in Poland as explanatory example supporting conceptual considerations proposed.

1. Introduction

Location strategies of firms and the embeddedness of economic activities across regions and countries have been particularly challenged by the new technological scenario connected to the fourth industrial revolution (Strange & Zucchella, 2017; Sturgeon, 2019). The broad theoretical debate on the advantages of agglomeration with respect to dispersed activities (Bathelt & Taylor, 2002; Biggiero, 2006; Boschma, 2005; Chiarvesio, Di Maria & Micelli, 2004; Götz, 2020; Lis, 2019) and the recent rise of technologies that suggests a reconfiguration in the way firms structure their activities – in particular when multinational companies are concerned (MNEs) (Ben-Ner & Siemsen, 2017; Cantwell, 2014) – motivates an updated exploration of the relevance of clusters in this context.

The paper aims at bridging the discussion on how clusters may stay attractive in the realm of the digital transformation for a specific type of entities – subsidiaries of MNEs. The novelty of this paper focuses mainly on the demonstration how cluster specific advantages work for foreign subsidiaries (FSs) in the time of Industry 4.0, by supporting the conceptual development with the case of an active cluster – the Aviation Valley in Poland – characterized by high presence of FSs and technological investments. On the one hand, the fourth industrial revolution outlines a different approach to manufacturing (smart factory) (Büchi, Cugno & Castagnoli, 2020) and innovation (Bogers, Hadar & Bilberg, 2016), where the relationship with the location of economic activities is put under scrutiny (Fratocchi & Di Stefano, 2020). On the other hand, specifically because of the strong interrelation between innovation and manufacturing processes in specialized industries that characterize clusters (Camuffo & Grandinetti, 2011), they could still be relevant places for FSs for the exploitation of opportunities related to Industry 4.0 technologies. We manifest that cluster advantages become even more visible in the digital age when cluster actors look for technological expertise and competences.

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The term Industry 4.0 (I4.0) embraces a wide array of interdisciplinary concepts and technologies – Cyber-Physical Systems (CPS), Internet of Things, Internet of Services, and Smart Factory (Hermann, Pentek & Otto, 2015), with different levels of maturity and market availability – which facilitate digitisation, automation and process integration along the value chains (Hermann et al., 2015; Kagermann, Wahlster & Helbig, 2013). From this perspective I4.0, research puts much emphasis on the potential to transform locations and organisation of manufacturing processes, where in particular it has been highlighted the possibility related to enhanced coordination related to hyper automation and hyper connectivity based on artificial intelligence (AI), big data, robotics, and Internet of Things (IoT) (Rüßmann et al., 2015). It impacts the structure of value chain activities worldwide and the location choices of MNEs, which is where new relationships emerge between tangible and intangible, manufacturing and innovation (Bianchi, Durán & Labory, 2019; Strange & Zucchella, 2017). In particular international business studies have stressed the relevance of knowledge seeking and knowledge exploitation dynamics in the behaviour of MNEs and their FSs, where also clusters have been included (Gereffi, De Marchi & Di Maria, 2017; Santos, Doz & Williamson, 2004).

Clusters are environments conducive for innovation, which goes in line with the observation by Cooke and Morgan (1998) who point to the fact that the processes of innovation became more collaborative. And many later studies point to the significance of knowledge management in clusters (e.g. Ciravegna, 2011; Dohse, Fornahl & Vehrke, 2018; Kesidou & Snijdersb, 2012; Lagendijk & Lorentzen, 2007; Morrison & Rabellotti, 2009; Zhang, Xu & Liu, 2011; Laufente et al., 2018). As far as I4.0 is concerned, studies on the impact of digitisation on clusters are in their infancy (Ciffolilli & Muscio, 2018; Götz, 2019; Götz & Jankowska, 2017, 2020; Hervas-Oliver, Estelles-Miguel, Mallol-Gasch & Boix-Palomero, 2019; Pawłyszyn, Fertsch, Stachowiak, Pawłowski & Oleśków-Szłapka, 2020, Bettiol, Capestro, De Marchi, Di Maria & Sedita, 2020a). The new technological scenario supporting the rise of the fourth industrial revolution has revealed even more the importance to manage knowledge in a proficient way not only in clusters of innovation (Engel, 2015) but in any type of clusters, as well (Götz & Jankowska, 2018; Puig, 2019). Thus, we developed our research on the foundation of the cluster's performance in the sphere of knowledge flows, knowledge spill-overs and learning processes (Boschma, 2005; Friedman, 2005).

The impact of I4.0 on the significance of clusters for MNEs' subsidiaries has to be further investigated and can be explored in the manufacturing field and in how innovation is managed, taking into consideration the tight relationship existing between these two areas within clusters and the consequences for home-grown and foreign actors operating in clusters (Hervas-Oliver, Belussi, Sedita, Caloffi & Gonzalez-Alcaide, 2020). I4.0 enables MNEs to better coordinate their operations on an international scale by establishing their foreign subsidiaries (FSs) in remote locations and source from these locations, thus the relevance of being a cluster actor in a foreign market is not that obvious. Nevertheless, some authors demonstrate that the I4.0 technologies may result in the growth of the relevance of operations on the local scale and reorganise or even shorten international production networks (Ben-Ner & Siemsen, 2017; Strange & Zuchella, 2017), shedding light on the opportunity for MNEs to be embedded into local manufacturing systems in Western countries or close to their final markets.

In this perspective our research question is *to outline the main cluster characteristics that could support FSs in their I4.0 investments and incentive FSs in being localized in clusters in the fourth industrial revolution scenario.* Bearing in mind the aim of the study, first we explain advantages of clusters in particular for FSs. It is followed by presentation of I4.0 key solutions in the cluster framework. Next, we briefly characterise the methodological aspects and the results referring to the context of the Aviation Valley in Poland. The paper ends with a conclusion, limitations of the study and propositions for further research.

2. Theoretical framework

2.1. Cluster-Specific advantages for foreign subsidiaries (FSs)

Cluster-specific advantages may be enjoyed by all cluster firms. However, the firm's origin – whether local or foreign – modifies the accessibility to these advantages. FSs search for locations characterised by conditions necessary for maximising inputs with the least costs and such that provide maximum benefit to companies and their objectives (Cano-Kollmann, Cantwell, Hannigan, Mudambi & Song, 2016). The factors of ownership, location and internalisation (OLI) determine FSs' performance and the level of strategic goal accomplishment (Narula, Asmussen, Chi & Kundu, 2019). When establishing their subsidiaries in foreign markets, MNEs tend to locate them near incumbent companies in related industries (Majocchi & Presutti, 2009; Bathelt & Li, 2017). Proximity to these entities is a kind of remedy against their lack of expertise in a specific market (Dow & Larimo, 2011; Yavan, 2010).

Other studies highlight the advantages for MNEs to locate within clusters also for production-related activities to gain from knowledge spill-overs connected to clusters and to the high level of specialisation characterising cluster firms (Belussi, 2018). To take full advantage of the location in a FSs have to invest in networking activities, by developing linkages with other actors operating in the cluster (Andersson and Forsgren, 1996, 2000; Schmid & Schurig, 2003). Embeddedness in a cluster is reflected in the eagerness and ability to adopt cluster-specific rules of conduct, cluster-specific routines, cluster benchmarks, a diversity of cluster partners t and functional areas to cooperate (Dacin, D Beal and Ventresca, (1999). Hence, FS's embeddedness in the local context impacts its performance (Birkinshaw et al., 2005; Cantwell & Mudambi, 2005; Yamin & Andersson, 2011).

FSs are not stand-alone units. MNEs may exploit the multi-locality of their FSs to combine local R&D with assets residing in other locations. Nowadays FSs became actors in the MNEs' knowledge augmenting and competence-building processes (Cantwell & Mudambi, 2005; De Beule & Van Beveren, 2019; Mudambi & Navarra, 2004). Bartlett and Ghoshal, 1987 point to four types of FSs, taking into account the strategic importance of the host market and the local environment. Besides the types of strategic leader, implementer and black hole, they also indicated the contributor. This is a FS operating in a host market with rather low importance for the parent company but with high internal competencies in terms of technology and R&D capability. Aware of the rather low significance of this host market, the parent company is more eager to allow the subsidiary to operate on its own. This type may then contribute the most to the knowledge pools of its MNE. Similarly, Gupta and Govindarajan (1991) develop a typology of FSs' roles based on knowledge flows in an MNE. They indicate the following FS roles with regard to knowledge flows: Global Innovator (high outflow, low inflow); Integrated Player (high outflow, high inflow); Implementer (low outflow, high inflow); and Local Innovator (low outflow, low inflow). Thus, FS capabilities and initiative in knowledge development are reflected in FS roles in innovation processes ranging from innovation adopter up to a centre of excellence (e.g. Frost, Birkinshaw & Ensign, 2002; Gupta & Govindarajan, 1991; Harzing & Noorderhaven, 2006). And being a cluster inhabitant may facilitate the knowledge development and innovation processes in FSs, specifically when the cluster is able to offer strategic knowledge related to its domain of specialization. From this perspective, FS relationships within a cluster play an increasingly important role in knowledge augmentation and competence-building processes of MNEs; becoming a "contributor," according to Bartlett and Ghoshal's (1987) framework. FSs' embeddedness in clusters, may accumulate the technological, market and managerial knowledge necessary to innovate.

Thus, where knowledge outflow from a FS is high, it is a Global Innovator or Integrated Player (Gupta and Govindarajan 1991). However, in the latter case, that of the Integrated Player, there is a threat that the high. inflow of knowledge from the parent company and other subsidiaries may leak out to other cluster actors. To sum up, the role a FS performs in the MNE network impacts the attractiveness of clusters for the FS.

2.2. Industry 4.0 and the role of clusters

The I4.0 scenario influences: innovation processes and manufacturing processes (Almada-Lobo, 2016; Holmström, Holweg, Khajavi & Partanen, 2016). Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, the Industrial Internet of Things (IoT), Cybersecurity, the Cloud, Additive Manufacturing, plus 3D printing and Augmented Reality create the pool of technologies typical of I4.0 (Rüßmann et al., 2015). I4.0 is based on six design principles: interoperability, virtualisation, decentralisation, real-time capability, service orientation, and modularity; these principles reflect I4.0′s horizontal and vertical integration. Horizontal integration manifests itself through value networks thanks to digitalisation that enables the integration of IT systems and smooth data flows between customers, suppliers and other external partners. Vertical integration is related to smooth data flows within the company along its value chain, from product design to sales (Kagermann et al., 2013). Horizontal integration creates more opportunities for small and medium-sized enterprises that surround and cooperate with large companies being often the flagship firms in networks. Vertical integration may support firm's coordination of distributed activities at a wider scale, sustaining connectivity within MNEs as well as in their international network (Cano-Kollmann et al., 2016; Cantwell & Salmon, 2018). From this perspective, specific locations can be conceived as contexts in which the implementation of I4.0 technologies is developed and tested to take into considerations the product and process requirements of the MNE (FSs) and to fit with the need of the FSs, while internationally the developed solutions are further applied. In particular, this could be the case of innovation such as I4.0 technologies that are not *"ready-to-use"* technologies, but that require specific projects for their implementation and adaptation to the industry requirements (Bettiol, Di Maria & Micelli, 2020b; Ortt, Stolwijk & Punter, 2020). As it occurred for other process/technological innovations that require tight connection between the development and the implementation phases or the design and production steps, the cluster becomes a relevant cognitive and relational environment where to carry out such innovation dynamics (Lazzeretti & Capone, 2016; Buciuni & Finotto, 2016).

Research on the dynamics of I4.0 investments at the cluster level highlights that cluster may leverage on the support of local institutions and peculiar innovation ecosystems enabling digital transformation (Benitez, Ayala & Frank, 2020; Hervas-Oliver et al., 2019). Due to the interaction and collaboration amongst firms (i.e. suppliers and buyers) as well as between the private and public actors within the clusters (Pagano, Carloni, Galvani & Bocconcelli, 2020), I4.0 technologies can be properly designed and applied to solve the specific industry requirements. From this perspective, the endowment of tangible and intangible resources available at the cluster level – technological infrastructures, local specialized competences, institutional fabrics – may favour the digital transformation (De Propris & Bailey, 2020). Moreover, studies on the adoption of I4.0 technologies for cluster firms compared to non-cluster one stress that I4.0 further sustain the cluster competitive model (Bettiol et al., 2020b).

The relevance of the cluster context for an effective development and implementation of I4.0 technologies at the business level can be observed considering servitization that may be facilitated by I4.0 technologies follows the development of competencies that contribute to the resilience of the local manufacturing industry (Kamp, Ruiz de Apodaca 2017; Sforzi & Boix, 2018; Bellandi & Santini, 2019). These competencies, rooted on the manufacturing experience available at the cluster level, may be recognised as locational assets that further increase the advancement of the configuration of competencies in geographical regions (Gebauer & Binz, 2019; Lafuente, Vaillant & Vendrell-Herrero, 2019) which "host" the clusters. As Götz and Jankowska (2017) point out, only the clusters equipped with expertise in IT solutions and knowledge adequate for the concepts of I4.0 will be attractive to firms and FSs involved in innovation. The knowledge-focused processes that result in innovation – creation, modification and the diffusion of knowledge – need a specific context. It has been noticed by many scholars that territory associated with relational space for innovativeness and knowledge processes is important, while much knowledge remains tacit and sticky to particular locations (Jerome, 2013; Malmberg & Power, 2005; Xue, 2018).

In the case when clusters have been approached by FSs for the exploitation of cluster manufacturing capacity and not necessarily also with an orientation to innovation, the role of clusters within the fourth industrial revolution could be different. The attractiveness of clusters for FS in times of the fourth industrial revolution may be determined by the core industry of the cluster. Some of industries are more prone to adopt new technologies and concepts and some less. From this point of view, I4.0 technologies can be implemented differently across industries. Referring to the specific I4.0 solution like the IoT, Buckely and Strange (2015) argue that it may lead to further division of labour, as particular location may specialise even more on particular operations or industries and, thus, core industries within clusters may become even more visible. The IoT means that products are equipped with sensors which collect and process data. Thanks to that, the coordination of MNEs may be easier. Simultaneously, communication between clusters may become easier and a number of clusters – each specialising in a particular field – may jointly create a value-creating network.

As far as robotics is concerned, this trend may reorganise the location patters of FSs, which in the case of manufacturing operations were established in low-cost economies (Buckley & Strange, 2015). The development of robots and their application in manufacturing processes may redesign value chain activities so that manufacturing processes may reshore back to advanced economies (Fratocchi & Di Stefano 2019). This trend may indicate the diminishing attractiveness of clusters for companies seeking in clusters efficiency advantages. Technology is the key facilitator for the reconfiguration of the production system and this may result in the movement of subsidiaries by parent companies to their home locations or other advanced countries which provide a better innovation context. As manufacturing processes in many industries concentrate in space, it may result in the damage of clusters more focused on manufacturing, which provided first and foremost cost advantages to their participants. Pegoraro, De Propris and Chidlow (2020) present different types of reshoring indicating that within the taxonomy of reshoring we may distinguish the home-shoring. On the contrary, in the case of clusters focused more on innovation, robotics may contribute to their growth. 3D printing may similarly diminish the relevance of manufacturing clusters, since this does not require any specific location, and firms do not have to relocate their production facilities to locations characterised by low production costs. On the other hand, this key I4.0 solution may lure manufacturers closer to their clients – end users of products and R&D organisations (Kinkel, 2020).

According to the above-mentioned analysis FSs can rely on clusters to exploit the specialized competences on product innovation and manufacturing process, the network of actors with the institutional support facilitating knowledge exchange to benefit from an effective development of I4.0 solutions.

3. Empirical section: industry 4.0, the aviation industry and the role of Polish cluster

One of the industries open for innovative technological solutions and quite much penetrated by multinational enterprises, thus characterized by existence of foreign subsidiaries within particular national markets is the aviation industry. Moreover, it is characterized by the presence of clusters. We will refer to this industry and the related Aviation cluster in Poland to provide evidence on the supportive role of cluster for FSs in the realm of I4.0.

Aviation is an industry conducive to the technologies and concepts of I4.0. In the pool of Aviation 4.0 concepts, we may distinguish: a) automatic flying in predefined situations in a rule-based way; b) developing a robust aircraft predictive maintenance; c) cockpit safety cognitive computing aid systems; d) real-time weather information update; e) improved search and rescue services especially for oceanic or remote areas; f) real-time Human Performance monitoring and alerting based on non-intrusive physiological sensors/signals and contextual information (Valdes & Comendador, 2018). From a manufacturing point of view, I4.0 technologies related to 3D printing and Augmented Reality may enhance product design, production and sustainability, mainly as far as maintenance tasks and spare parts management are concerned (Ceruti, Marzocca, Liverani & Bil, 2019).

This industry is also one of the most globalised sectors. The features of the product – aircraft – allow MNEs to disperse their FSs in the most attractive places. R&D operations in the aviation sector are extremely expensive and this fact, combined with very capital-intensive manufacturing processes, make the production of an aircraft by a single company practically impossible. Meanwhile, current motives for FDI are related to strategic assets like knowledge and expertise seeking. From this point of view, thanks to their identity and features that work as a laboratory for I4.0, clusters may help the aviation industry to cope with the new technological challenges and keep the risk assurance requirements high by even better respecting the priority of environmental sustainability.

3.1. Methodological approach

In order to manifest how clusters may stay attractive for FSs in times of the fourth industrial revolution, we adopt a qualitative methodology by using as an exploratory case study the aviation cluster – the Aviation Valley in Poland. Following the typology of case studies developed by Yin (2017)) an exploratory character for the case study was used on purpose, because it helps to understand the context and setting of a phenomenon (Dyer, Gibb & Wilkins, 1991; Guba & Lincoln, 1994; Langley, 1999).

We selected the Aviation Valley in Poland since it represents one of the best performing clusters in Poland, and it is the host location for FSs of the crucial players in the aviation industry. It is one of four Key National Clusters in Poland.[1] The group embraces clusters which play very important role in the Polish economy and are characterised by relatively higher level of international competitiveness than other clusters in Poland. Key National Clusters poses strengths and great potential to grow within the following six areas: human resources, infrastructure and financial resources, economic potential, knowledge creation and knowledge transfer, contribution to the public policy, focus on the clients. These areas are the fields of evaluation of the developmental potential of a cluster. A cluster to be named the Key National Cluster is evaluated with a set of indicators (Kuza, 2018): its size and structure (number of participated SME and large companies); employment structure; joint activities of cluster participants and internal collaboration; geographical concentration of cluster participants; cluster specialization; rate of R&D projects; innovation performance; resources (physical, human, financial, etc.); presence of the cluster and its companies in foreign markets; national and international visibility of the cluster; cluster coordination services and management .

Nowadays according to the Central Statistical Office in Poland there are 232 enterprises that represent the NACE Rev. 2.0 class of 30.30.Z - Manufacture of air and spacecraft and related machinery and 43 of them operate in the region where the Aviation Valley is located and are associated within the cluster organization. Another important group of entities that contributes to the existence of the aviation cluster are 1156 companies of NACE Rev. 2.0 class 26.51 - Manufacture of instruments and appliances for measuring, testing and navigation. 24 of them are located in the area of the aviation cluster and are involved in the cluster organization. The aviation cluster embraces enterprises dedicated to aviation and representing supporting and related industries. According to the data from the manager of the cluster organisation, there are 138 companies located in this cluster, which focus on the aviation industry and employ 28,443 people. Their revenue in the period 2015–2017 totalled up to more than 8.1 billion Euro.

In the Aviation Valley in Poland many solutions for the industry are designed and developed, while many items for aircrafts are produced, thus providing a combination of cluster processes related to manufacturing and innovation that fits with the challenges the fourth industrial revolution constitutes for MNEs. The Valley represents the concentration of companies, R&D institutions and business-support organisations focused on the aviation industry and the industries that represent the supporting and related to the aviation sectors.[2]

The case study is based on primary and secondary data, so we used respectively the data collected from first-hand sources with the presented research project in mind using direct interviews. Secondary data sources were the reports from the Polish Investment and Trade Agency on the attractiveness of Poland for foreign investors representing the aviation industry, reports on clusters in Poland, but also certain materials published on the Internet, including articles in the business press.

The primary data were collected through face-to-face interviews with the manager of the cluster organisation, representatives of the R&D sector and managers representing 20 out of 138 cluster companies associated within the cluster organisation. These 20 firms were chosen purposefully. The composition of the group of these 20 firms whose representatives shared their views on the attractiveness of clusters for FSs was to embrace both – domestic and foreign-owned entities, companies involved in diverse operations along the whole value chain; starting from design and testing through modification and implementation of the constructed aircraft – including unmanned aircraft and other components for the aviation industry – to support services for clients and the key aspect was their involvement in any of the I4.0 technologies. Thus, eventually interviews were conducted with 11 companies just with the Polish capital and 9 companies with foreign capital in their ownership structure. Their characteristics reflect the profile of firms active in the Valley presented more in Section 3.2.2. These companies represent diverse industrial background indicated by the NACE Rev. 2.0 code, nevertheless they perform operations typical for entities from industries supporting aviation or that are related to aviation. In particular amongst the selected companies there were entities involved in 3D printing and prototyping (scanning), augmented reality solutions and Internet of things. FSs that participated in the interviews are medium and large enterprises. Domestic entities are small and medium companies. The group of FSs are manufacturing companies. And the domestic firms are service and manufacturing organisations.

The direct unstructured interviews were carried out in February 2020. In our research we refer to the triangulation of data sources in order to create a comprehensive understanding of phenomena (Patton, 1999). Our research was developed by specifically considering the four dimensions of cluster-related advantages suggested in the literature: inter-firm cooperation, the role of human capital (workforces), R&D collaboration, and international linkages. Representatives of cluster companies were asked if they are familiar with

[1] https://www.gov.pl/web/rozwoj-praca-technologia/lista-kkk

[2] https://www.paih.gov.pl/sectors/aerospace

the term I4.0, about their direct involvement in projects that refer to I4.0 technologies and the involvement of other cluster entities in projects that exploit the I4.0 solutions. In the next section we present facts and data collected during the interviews combined with the data from secondary sources.

3.2. Case analysis - The Aviation Valley in Poland

3.2.1. Cluster background

The Aviation Valley is located in South-Eastern Poland, in Podkarpackie Voivodship, within the Special Economic Zone. The spatial concentration of entities focused on the aerospace industry in this location is very high, and the formal organisation was developed to be a platform for cooperation and communication amongst cluster actors and with partners from outside the cluster. There are around 155 entities (companies and other organisations) operating within the cluster.[3] The creation of this cluster was initiated by companies located in this area. Nevertheless, aviation firms in Poland operate not only in this location but also in the Western and Central part of the country.

The growth of this industry was quite noticeable during the interwar period. In those days, the Polish aviation industry was famous for light aircraft, gliders, engines and avant-garde construction solutions (PlaFIA, 2013, p. 4). In 1936, the Polish government started the initiative and five-year project called the Central Industrial Region (COP) (PlaFIA, 2013, p. 4), which was one of the biggest economic projects in the Second Polish Republic. The Second World War interrupted its implementation, though it was reactivated after the war. Two big factories in the Podkarpackie Province were planned, the aircraft factory in Mielec and the aircraft engine and artillery factory in Rzeszów. The emergence of a great pool of academics and engineers focused on the aviation industry helped the sector to develop practically from scratch shortly after 1945, and such human resources played a paramount role in the reconstruction of the aviation industry at the beginning of the political and economic transformation in Poland. The 1990s brought a visible reduction in the workforce in this sector, by almost 50%; that is, up to 40,000 people. amongst them were many top professionals with great expertise in technology.

In 2004, when Poland joined the European Union, new sources of funding appeared, i.e. the Framework Programmes, CleanSky, DREAM, SCARLET, and OPENAIR. The perception of Poland in the world has improved and the risk of doing business in Poland decreased. It was a very important message for foreign (PlaFIA, 2013, p. 7). In the cluster, the first FDIs were done by large relevant companies in the industry: Pratt & Whitney, Sikorsky, Augusta, Hispano-Suiza and MTU. Their entry accelerated the growth of the Valley, since they were flagship manufacturers of engines and aircraft parts. They developed their network of local suppliers and, thus, supported the growth of local family businesses.[4]

The collaboration between FSs and R&D actors in the cluster have been particularly intense since the beginning of the cluster. General Electric Company (GE) and the Łukasiewicz Research Network – Institute of Aviation (ILOT), which is the founder of the cluster organisation (namely that corresponds with the presented aviation cluster: the Aviation Valley) are close partners. The manifestation of their cooperation are tests for bearings and fans used in aircraft engines (Stężycki, Wiśniowski, 2016). Similar tests were conducted for Pratt & Whitney and for Rolls Royce who are the main players in the aviation industry. This kind of cooperation calls for high quality competences and unique professional laboratories (e.g. bearing lab and combustion chamber in ILOT). That is why aviation companies look for attractive locations with knowledge pools and the Aviation Valley in Poland is one of such locations.

3.2.2. Cluster actors: Domestic and foreign firms as the pool of cooperating entities

The cluster embraces FSs of MNEs and many local firms. The structure of the industry is dominated by SMEs with the visible involvement of family firms. Despite their size and, thus, their relatively high vulnerability to turbulences in their environment, these firms have been able to become attractive partners for demanding well-known actors in the world aviation industry like Boeing and Airbus. Thanks to their expertise, Polish family-owned SMEs have provided some of the most sophisticated parts for Boeing 737 s, the Boeing 787 Dreamliner and Airbus 380 s. As a kind of confirmation of the position in the world of the Polish Aviation Valley, let us mention the fact that practically every aircraft in the world is equipped with one or more items from Poland. amongst the corporate actors in the Valley are FSs of companies mainly from the USA, Italy, France, the UK and Canada. These FSs have been producers of aviation and high-tech equipment. In 2017, Rolls-Royce and Safran opened a new factory – Aero Gearbox International Poland – in the Valley, a factory that produces engines.[5] Another example of a FS dedicated to manufacturing in the Aviation Valley is Bodycote, which produces aircraft engine components as well as chassis components for aircraft.[6] They also conduct laboratory tests on microstructures and the properties of alloys used in the aviation industry.

As far as I4.0 is concerned, two ongoing processes can be observed. On the one hand, there are firms acquainted with I4.0, such as 3D Robot Sp. z o.o., which develops and implements innovative robotic technologies dedicated to plants operating in the broadly defined aviation industry. This is in line with the innovative potentialities related to cluster dynamics, in which specialised suppliers (also new firms) can support broader technological (and product) enhancement at the cluster and industry level. On the other hand, in the group of the leading foreign investors in the Valley are EME Aero, SAFRAN Transmission Systems Poland, Pratt & Whitney, Collins Aerospace, MTU, WSK Świdnik, a Leonardo Helicopters Company, Heli One and General Electric. Such companies are involved in projects that exploit Big Data technologies, 3D printing and artificial intelligence. The biggest cluster firms with foreign origin cooperate with specialized cluster suppliers and R&D institutions. Cluster cooperation is crucial and is the foundation for the broader cooperation within the Clean Sky 2 project (Fig. 1 below).

3.2.3. R&D entities in the cluster: Knowledge pool in the era of Industry 4.0

One of the leading R&D entities in the Aviation Valley is the Centre of Advanced Technologies "AERONET Aviation Valley" established in 2004 (PlaFIA, 2013, p. 8). This institution is coordinated by the Rzeszów University of Technology. It has the legal form of a consortium dedicated to facilitating cooperation between business and academia. Through joint projects, the consortium develops the most sophisticated technological solutions. The Rzeszów University of Technology is very much engaged in research focused on the aviation industry, so much that it established the Materials Research Laboratory for the aviation industry. In Europe, it is one of the most advanced laboratories doing research in modern manufacturing technologies, including plastic forming and surface engineering, which is related to aspects of 3D printing.

Another consortium is the Cold Flow Turbine Test Facility. It is a joint project of Avio Polska WZL Nr 4 S.A. and the research-industrial consortium Laboratorium Badań Napędów Lotniczych "Polonia Aero," but also two entities from outside of the cluster: the Warsaw University of Technology and the Military University of Technology.

[3] http://rzeszow.wyborcza.pl/rzeszow/7,34962,21831008,dolina-lotnicza-ma-inwestycyjne-zniwa-11-nowych-fabryk.html
[4] http://rzeszow.wyborcza.pl/rzeszow/7,34962,21831008,dolina-lotnicza-ma-inwestycyjne-zniwa-11-nowych-fabryk.html
[5] https://www.defence24.com/industry/new-aviation-industry-facility-in-poland-rolls-royce-and-safran-investment-in-the-subcarpathian-voivodeship
[6] https://www.bodycote.com/pl/press-release-uk-pl/bodycote-to-open-new-plant-in-poland/

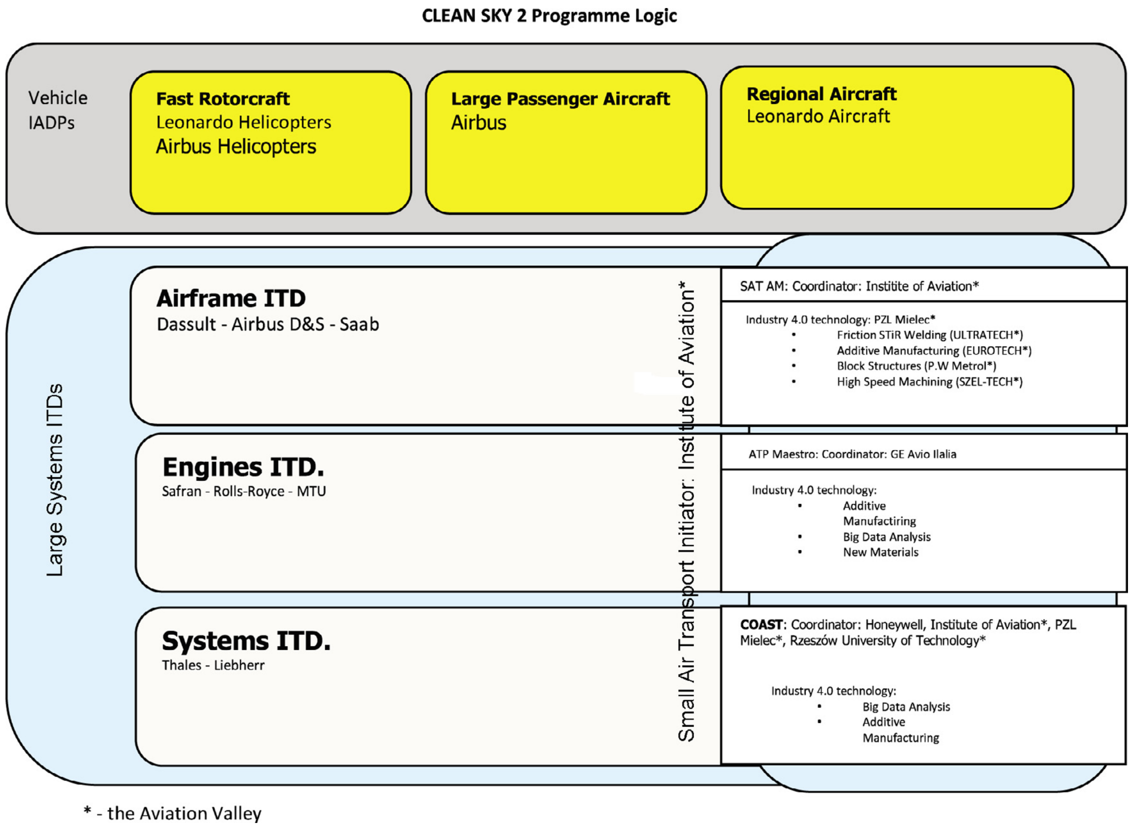

Fig. 1. Clean Sky 2 program: cooperation within I4.0 technologies Source: own elaboration based on European Commission (2017); (Piwek & Wiśniowski, 2016).

The facility is one of the most modern industrial research and development laboratories concentrated on testing low-pressure turbine prototypes worldwide. This investment is worth EUR 50 million.

The strength of the R&D sector in the Aviation Valley is to some extent the result of cooperation between the Polish Aviation Technology Platform and the National Research and the Development Centre under the leadership of the InnoLot Programme,[7] based on a formal agreement. The National Research and Development Centre has been obliged to invest around EUR 73 million (60% of the budget of the project) in research, development and measures supporting the transfer of results to the aviation sector. The remaining 40% have been provided by the members of the following associations: Aviation Valley in Rzeszów, Wielkopolski Aviation Cluster in Kalisz and the Bielsko Federation of Airline Companies in Bielsko-Biala. Financing only went to projects that deliver tangible commercial gain to the industry. The research projects have so far resulted in around 30 Polish prototypes and technology demonstrators developed with the use of 3D printing and robotics.

Other than the initiatives of external companies, we should mention research centres established by cluster firms. For example, the company WSK "PZL-Rzeszów" S.A. (now Pratt & Whitney Rzeszów) implemented the project "The Creation of a Research and Development Centre for Aircraft Propulsion Systems." This initiative was co-financed by the European Regional Development Fund; European Union funds within the Operational Programme: Development of Eastern Poland 2007−2013; Priority axis 1. Modern Economy; and Measure 1.3 Promoting Innovation. The project was to finance the construction of a building for the needs of the design and technology office, adaptation and renovation of facilities which will house engine test beds, but also the purchase of scientific and research machinery and equipment.[8] The project was implemented during the period 2012−2015 and created new opportunities for design and engine testing at WSK Rzeszów. Another research centre is the Aircraft Research and Testing Centre at PZL Mielec, which became famous due to its manufacturing of helicopter cabins for the Black Hawk.[9] The testing processes used prototypes developed with 3D printing technology and Augmented Reality solutions.

3.2.4. *Qualified workforce: Key strength in the ra of Industry 4.0*

The long tradition of the aviation industry in Poland is related to the educational possibilities in this sector. Many major cities of Poland have Universities that offer programmes for aviation engineers. These education institutions are dispersed all around Poland so − although Rzeszów University of Technology is situated within the Aviation Valley − graduates from all the above universities are employed by cluster companies, with the pool of potential employees reinforced each year by around 20,000 of new professionals.

To provide human resources with a profile required by the industry, there happen constant interactions between universities and cluster-related companies, during which they discuss their expectations in terms of staffing. Cluster firms, universities and secondary schools together promote studies in engineering programmes, while teachers are trained in aviation companies within the cluster or even beyond, in other regions of Poland and abroad. Training courses abroad are possible thanks to the fact that there are subsidiaries of foreign companies in the Aviation Valley. The courses offered by education institutions, R&D entities in Poland and training provided by foreign firms focus much on the I4.0 solutions, in particular 3D printing. This kind of approach is very much justified by the still relatively

[7] https://www.ncbr.gov.pl/fileadmin/user_upload/import/tt_content/files/1__informacje_ogolne.pdf

[8] http://www.pwrze.com/en/eu-projects-and-tenders

[9] http://www.pzlmielec.pl/en/media/news/art,103,300-reasons-to-celebrate-for-employees-at-pzl-mielec.html

low adoption of 3D printing and robotics in Poland. Only 2% of enterprises in Poland uses 3D printing in general, with only 1% for prototypes or models for sale. However, 5% of enterprises declared the use of industrial robots in 2018.[10]

There is a need for the professional teaching of students about appropriate machinery, tools and software, so cluster firms provide them together with the training facilities. Since 2016, companies in the cluster took patronage over 12 schools in the region – technical colleges and Practical Training Centers – and the whole project has been co-financed by the Voivode Office. This cooperation is the essence of the project – the Training centre for Numerically Controlled Machine Operators – that emerged thanks to the agreement signed by the cluster organisation Aviation Valley and the above-mentioned schools, the best ones in the region. Workplaces are available not only in production but also in R&D, where around 300 new people are needed each year, and the demand for skilled workers is growing. Training courses and internship programmes in leading firms are popular. An example of the cooperation are such programmes as Aviation Management at the School of Information Technology and Management in Rzeszów or Air Transport Infrastructure at the Cracow University of Technology, with graduates able to find jobs in the Aviation Valley. The development of programmes dedicated to the aviation industry has been possible thanks to European Union funds.

What plays a great role in the cooperation between business, R&D and education institutions is the cluster organisation that promotes and supports the implementation of a set of actions. According to the cluster manager, a great emphasis has been put on teaching physics to students in junior high schools and high schools. For younger kids, cluster organisation helped to develop the Technical University. The Faculty of Mechanical Engineering and Aeronautics of the Rzeszów University of Technology offers dual studies in the "Integrated training of personnel for the aviation industry." The study program is based to a large extent on analyses carried out in modern production plants, which take under consideration the need to redefine the business models of aviation firms following I4.0 premises. A separate program is targeted at high school teachers. One of the key companies – Pratt & Whitney Rzeszów –organises for teachers of the profession regular sessions, visits to production departments, meetings to share knowledge and good practices with respect to I4.0 solutions. The company co-finances the participation of schools from Rzeszów and the surrounding area in nationwide competitions and the organisation of technical and science competitions (Olimpiady). The company took patronage over some classes in schools, first in the Mechanical School Complex, then also in the Technical School Complex. The patronage is to support the education of highly qualified personnel for the aviation industry through a traineeship and internship program. All this is to allow students to gain practical experience in a real business environment penetrated by I4.0 challenges.

Aware of the need to develop the environment for the development of technology and the conditions for implementing I4.0, the Aviation Valley develops soft skills for the European Aerospace Industry in the era of Sky 4.0. The Aviation Valley implements an international educational program whose goal is to help Aeronautical companies from a different European country to meet the challenges of Industry 4.0 by improving the soft skills of their human resources. The implementation of work on the project involves not only Polish (e.g. PZL Mielec) but also foreign members of the Aviation Valley (Pratt & Whitney). This is to further integrate FS with local partners at the Aviation Valley and to jointly develop the best practices for creating a friendly environment for the development of technologies and employees of industry 4.0.

Currently, the Aviation Valley Cluster coordinates a project entitled Sky 4.0 as part of the ERASMUS + program, which aims to build curricula on soft skills necessary to implement I4.0 solutions and technologies in the aviation sector, namely character skills, social competences and personal development skills.

3.2.5. Cluster as a platform for international cooperation in the era of Industry 4.0

The Aviation Valley companies are involved in the Clean Sky 2 program. It is a public-private partnership (PPP) between the European Commission and the EU aviation industry (Fig. 1). The Aviation Valley is part of the program and participates in that via the Institute of Aviation which is indicated in Fig. 1. amongst entities involved in this program we may indicate the Polish domestic companies (such as Ultratech - http://ultratech.pl/en/about-us-2/, Eurotech - http://eurotech.com.pl/en/home-2/, Szel-tech - http://szel-tech.pl/index.php?lang=en), and the Polish R&D organisations (such as the Aviation Institute), and PZL Mielec (http://www.pzlmielec.pl/en/) a large company being a foreign subsidiary of Lockhed Martin.

As part of the Clean Sky program, technologies are developed with the aim of meeting the quality parameters (release of carbon dioxide – CO2, nitrogen oxides – NOx, noise emissions reduction), reinforcing the competitiveness of the European aviation industry and increasing the availability of air services through diverse services. The Clean Sky 2 structure includes joint demonstrations and simulations at the full vehicle level through Innovative Aircraft Demonstrator Platforms (IADPs).

The project activities include Small Air Transport (SAT), initiated by the Research Network Łukasiewicz – Institute of Aviation from Poland. The SAT's mission is to provide an accessible and affordable high-speed mode of transport in the European interregional network of connections. Members of the Aviation Valley are involved in all areas of SAT, both Polish companies and institutes, but also foreign partners who invested in the Aviation Valley. I4.0 technologies are being developed that allow the implementation of the SAT activity. In the Airframe area, coordinated by the Łukasiewicz Research Network – Institute of Aviation, the most desirable technologies of I4.0 are: Friction STiR Welding, Additive Manufacturing, Block Structures, and High-Speed Machining. In this area, five companies and a research institute – members of the Aviation Valley – participate in the implementation of the project.

The coordinator of another project from the Engines ITD area under SAT is GE Avio Italia, which is part of GE Co. GE belongs to a group of large investors in the Aviation Valley. In the ITD Engines area, the key developed I4.0 technologies are Additive Manufacturing, Big Data Analysis and New Materials (mainly resistant to high temperatures). Third area (Systems ITD) – the Cost Optimized Avionic SysTem – is coordinated by Honeywell and the Institute of Aviation and Rzeszów University of Technology. The project focuses on investigations, testing and delivery of key novel avionic technologies capable of tackling the most challenging tasks in the area of avionic solutions. These tasks generally concentrate on searching for twofold results: the reduction of costs and development towards single-pilot cockpit solutions. The Rzeszów University of Technology and Łukasiewicz Research Network – Institute of Aviation are working together on the latter: the Flight Reconfiguration System (FRS). This is the avionic sub-system designed to solve the problem of possible abrupt pilot/crew incapacity to continue controlling the flight (e.g. in case of abrupt death, loss of consciousness, loss of geographical awareness, etc.). It is also worth emphasising that – in addition to local enterprises – members of the Aviation Valley, the SAT program includes transnational corporations such as Leonardo Helicopters Co and GE Co. Thus, the Aviation Valley operates like a platform for cooperation at the international level.

In addition to this evidence, we should mention that the cluster organisation of the Aviation Valley is involved in the cooperation with other cluster organisations within the European Aerospace Cluster Partnership (http://www.eacp-aero.eu/). This partnership is dedicated to the implementation of I4.0 (in particular, to the interconnected smart-factory, robotics, the automation of production and logistic processes, the development of common quality standards).

4. Discussion

The Polish Aviation Valley manifests cluster-specific advantages and reflects the attractiveness of clusters for FSs in the era of I4.0. Companies in the Aviation Valley, in particular FSs, are cooperating with other entities within ambitious projects such as those related to the I4.0 context. The implementation of I4.0 may be considered a complex process that requires fundamental new competences, culture and organizational change, as well as openness and trust within the value chain Ortt et al., (2020). In this scenario being embedded into a cluster for a firm – and in particular for a FS – may become a successful strategy since clusters represent conducive knowledge environments connected to the specific industry domain of I4.0 implementation and use, but also socio-institutional contexts reducing uncertainty (Götz, 2020). Very intense real cooperation between business and academia in the Aviation Valley allows FSs for the sourcing of technological, market and managerial knowledge necessary to innovate. Thus, not the lower labour cost is the key factor that make this location a sticky place for MNEs, but the context prone to knowledge creation, dissemination and further to innovation – penetrated by many diverse R&D institutions and domestic companies equipped in knowledge and sophisticated skills. The manifestation of this phenomenon is the Clean Sky 2 program, in which the Aviation Valley entities are involved. The involvement of the Aviation Valley actors in this program, in particular the Polish domestic companies, and the Polish R&D organisations and a subsidiary of one leading multinational enterprise in the aviation industry is a strong and visible manifestation that the Aviation Valley does not focus nowadays on the reduction of costs but its entities are capable to create technological innovation.

The embeddedness of FSs in the Valley is confirmed by their openness to interactions with the R&D sector and local firms, which often act as suppliers. Consistently with studies highlighting place-based policies supporting effective I4.0 projects at the territorial level (De Propris & Bailey, 2020; Hervas-Oliver et al., 2019), the cluster and cluster organisation facilitate the implementation of I4.0 not only in the technological but also through their organisational dimension, not to mention their presence as an integrative element of the whole clusters' systems in this industry. The existence of the Valley as a specific cluster entity acting as local dynamic actor (Gereffi et al., 2017) allows both cluster firms and FS to reduce transaction costs. Such transaction costs do not refer to production cost, rather to the costs related to find reliable partners for ambitious, knowledge-intensive projects such as I4.0 ones. From this perspective, the degree of cluster maturity coupled with FS long-term investments within the cluster – as demonstrated in the Poland Aviation Valley - may represent positive conditions for FSs in the development or implementation of effective, valuable I4.0 initiatives.

As the case study suggests, the attractiveness of clusters for FSs may be further reinforced when cluster members are characterised by world-class technological level, and it will be appreciated by technological leaders. This requirement refers to activities and operations at each level of technological readiness (TRL): starting from tests up to the final mass manufacturing processes. The cooperation of cluster members with technological leaders contributes to the legitimisation and, thus, attractiveness of clusters. It is of great importance in times of I4.0, when the cost of mistakes depending on the selection of inappropriate partners in high-tech sectors is extremely high. Being at the technological frontiers (i.e. in the case of the aviation domain) and being able to constantly offer updated knowledge and support for innovation by cluster firms – suppliers and firms in the supporting industries – represents a key asset for FSs looking for experienced partners for I4.0 projects. In particular through agglomeration clusters may offer a high number of potential partners within a context of cluster internal heterogeneity (Gereffi et al., 2017; Menzel & Fornahl, 2009). I4.0 calls for multisectoral and multi-technological thinking on the site of cluster members. A good example of this approach is the work on the new ATP GE engine that utilises 3D printing technologies, Big Data Analytics, robots in the manufacturing processes and research on new fuel materials. Nowadays we observe shift towards smart manufacturing on the side of FSs in the Aviation Valley but if this trend will prevail it is too early to conclude.

Cooperation in clusters can contribute to the introduction, and later application, of I4.0 solutions. On the one hand, clusters may serve as a laboratory to test new ideas and solutions. On the other hand, they make easier the search for specialised business partners and the support provided by public bodies. These are advantages for cluster entities regardless of their origin. Even if MNEs that establish their FSs within clusters may face the liability of foreignness, thanks to the nature of clusters – reflected in pro-cooperative climate – FSs in clusters are better equipped to cope with the burden of not being a local company. Links to local entities positively influence the legitimacy of a FS. Moreover, thanks to the configuration and coordination of their operations, MNEs may exploit cluster advantages provided by different locations. In the context of I4.0, clusters may become bridges in the global space and foreign subsidiaries equipped with relations with their host market partners may further internationalise creating links with entities in other clusters, further reinforcing knowledge exchange connected to I4.0 investments. FSs act as gatekeepers further pushing innovation connected to I4.0 within the cluster (Hervas-Oliver et al., 2020) but at the same time clusters can become new platforms for technological innovation worldwide further nurturing I4.0 strategies of MNEs.

5. Conclusion

The study presented in this paper was to combine the concept of cluster attractiveness with the concept of I4.0; the study was conducted from the perspective of MNEs establishing their subsidiaries in clusters. By doing so, we looked for arguments whereby – despite the trend towards digitalisation, technological advancements and the emergence of cyber-physical systems – locating an FS within a cluster may still be attractive. In this way, we presented how clusters may be useful in the new reality and how the fourth industrial revolution may redefine cluster attractiveness. The Aviation Valley in Poland is a tangible example of the still noticeable attractiveness of clusters for FSs. In relation to other industries, the aviation industry is very much infiltrated by I4.0 solutions and its participants are still eager to cluster. Thus, we need to explore how the attractiveness of clusters will work in case of less technologically innovative industries. However, we may assume that since I4.0 is much about technological but organisational innovation, as well clusters may stay attractive for FSs in industries that are penetrated more by non-technological innovation.

The study suffers from certain limitations. The biggest drawback is the focus on just the aviation cluster and in just one location. The next step is to broaden the study and provide international clusters' comparisons. Another thing is the necessity to deepen the results and conduct further qualitative analysis with cluster firms so as to compare the perception of reality amongst local firms and FSs to further evaluate whether the I4.0 adoption has been pushed by FSs or local firms also have a proactive role in such dynamics. Another future stream of research could use the story about the Aviation Valley in Poland to explain how high-tech manufacturing clusters in the industrialising Eastern EU countries also re-emerged under the push of various types of investment strategies by MNEs, which will contribute to the discussion by Cowling and Tomlinson (2011), who argue that to ensure economic development we need economic governance structures that serve the wider public interest.

References

Almada-Lobo, F. (2016). The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES). *Journal of Innovation Management*, *3*(4), 16–21.

Andersson, U., & Forsgren, M. (1996). Subsidiary embeddedness and control in the multinational corporation. *International Business Review*, *5*(5), 487–508.
Andersson, U., & Forsgren, M. (2000). In search of centres of excellence: Network embeddedness and subsidiary roles in multinational corporations. *Management International Review*, *40*(4), 329–350.
Bartlett, Ch.&, & Ghoshal, S. (1987). Managing across Borders: New Organizational Responses. *Sloan Management Review*, *29*(1), 43–53.
Bathelt, H., & Li, P. (2017). From temporary market to temporary cluster: Evolution of the Canton Fair. *Area Development and Policy*, *2*(2), 154–172.
Bathelt, H., & Taylor, M. (2002). Clusters, power and place: Inequality and local growth in time−space. *Geografiska Annaler: Series B, Human Geography*, *84*(2), 93–109.
Bellandi, M., & Santini, E. (2019). Territorial servitization and new local productive configurations: The case of the textile industrial district of Prato. *Regional Studies*, *53* (3), 356–365. doi:10.1080/00343404.2018.1474193.
Belussi, F. (2018). New perspectives on the evolution of clusters. *European Planning Studies*, *26*(9), 1796–1814.
Benitez, G. B., Ayala, N. F., & Frank, A. G. (2020). Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. *International Journal of Production Economics*, *228*. doi:10.1016/j.ijpe.2020.107735.
Ben-Ner, A., & Siemsen, E. (2017). Decentralization and localization of production. *California Management Review*, *59*(2), 5–23.
Bettiol, M., Capestro, M., De Marchi, V., Di Maria, E., & Sedita, S.R. (.2020a). Industrial districts and the fourth industrial revolution. *Competitiveness Review*. 10.1108/CR-12-2019-0155
Bettiol, M., Di Maria, E., & Micelli, S. (2020b). Industry 4.0 and knowledge management: An introduction. In M. Bettiol, E. Di Maria, S. Micelli (Eds.), *Knowledge Management and Industry 4.0* (pp. 1−18). Cham: Springer. doi:10.1007/978-3-030-43589-9_1.
Bianchi, P., Durán, C., & Labory, S. (2019). *Impact of Industry 4.0 on Manufacturing. Transforming Industrial Policy for the Digital Age*. Edward Elgar Publishing.
Biggiero, L. (2006). Industrial and knowledge relocation strategies under the challenges of globalization and digitalization: The move of small and medium enterprises among territorial systems. *Entrepreneurship and Regional Development*, *18*(6), 443–471.
Birkinshaw, J., Hood, J., & Young, N. S. (2005). Subsidiary entrepreneurship, internal and external competitive forces, and subsidiary. *International Business Review*, *14*, 227–248.
Bogers, M., Hadar, R., & Bilberg, A. (2016). Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technological Forecasting and Social Change*, *102*, 225–239. doi:10.1016/j.techfore.2015.07.024.
Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, *39*(1), 61–74. doi:10.1080/0034340052000320887.
Büchi, G., Cugno, M., & Castagnoli, R. (2020). Smart factory performance and Industry 4.0. *Technological Forecasting and Social Change*, *150*, 119790 November.
Buciuni, G., & Finotto, V. (2016). Innovation in global value Chains: Co-location of production and development in italian low-tech industries. *Regional Studies*, *50*(12), 2010–2023. doi:10.1080/00343404.2015.1115010.
Buckley, P. J., & Strange, R. (2015). The governance of the global factory: Location and control of world economic activity. *Networked multinational enterprises in the modern global economy*. Edward Elgar.
Camuffo, A., & Grandinetti, R. (2011). Italian industrial districts as cognitive systems: Are they still reproducible? *Entrepreneurship & Regional Development*, *23*(9−10), 815–852. doi:10.1080/08985626.2011.577815.
Cano-Kollmann, M., Cantwell, J., Hannigan, T. J., Mudambi, R., & Song, J. (2016). Knowledge connectivity: An agenda for innovation research in international business. *Journal of International Business Studies*, *47*(3), 255–262. doi:10.1057/jibs.2016.8.
Cantwell, J. (2014). Location and the multinational enterprise. In J. Cantwell (Ed.), *Location of International Business Activities: Integrating Ideas from Research in International Business. Strategic Management and Economic Geography* (pp. 261−273). Palgrave Macmillan.
Cantwell, J., & Mudambi, R. (2005). MNE competence-creating subsidiary mandates. *Strategic Management Journal*, *26*(12), 1109–1128.
Cantwell, J., & Salmon, J. (2018). The effects of global connectivity on knowledge complexity in the information age. In R. van Tulder, A. Verbeke&, L. Piscitello (Eds.), *International Business in the Information and Digital Age* (pp. 123−137). London: Emerald.
Ceruti, A., Marzocca, P., Liverani, A., & Bil, C. (2019). Maintenance in aeronautics in an Industry 4.0 context: The role of augmented reality and additive manufacturing. *Journal of Computational Design and Engineering. Society for Computational Design and Engineering*, *6*(4), 516–526.
Chiarvesio, M., Di Maria, E., & Micelli, S. (2004). From local networks of SMEs to virtual districts? *Research Policy*, *33*(10), 1509–1528.
Ciffolilli, A., & Muscio, A. (2018). Industry 4.0: National and regional comparative advantages in key enabling technologies. *European Planning Studies*, *26*(12), 2323–2343. doi:10.1080/09654313.2018.1529145.
Ciravegna, L. (2011). Technological learning in the Silicon Valleys of Latin America. *Journal of Development Studies*, *7*(48), 1178–1198.
Cooke, P., & Morgan, K. J. (1998). *The Associational Economy: Firms, Regions, and Innovation*. Oxford University Press. doi:10.1016/S0048−7333(02)00123−3.
Cowling, K.& ., & Tomlinson, P. R. (2011). Post the 'Washington Consensus': Economic governance and industrial strategies for the twenty-first century. *Cambridge Journal of Economics*, *35*(5), 831–852. doi:10.1093/cje/ber003 September 2011.
Dacin, T., D Beal, B., & Ventresca, M. (1999). The embeddedness of organizations: Dialogue & directions. *Journal of Management*, *25*(3), 317–356.
De Beule, F., & Van Beveren, I. (2019). Sources of open innovation in foreign subsidiaries: An enriched typology. *International Business Review*, *28*(1), 135–147.
De Propris, L., & Bailey, D. (2020). Industry 4.0 and regional transformations. Industry 4.0 and Regional Transformations. 10.4324/9780429057984
Dohse, D., Fornahl, D., & Vehrke, J. (2018). Fostering place-based innovation and internationalization−the new turn in German technology policy. *European Planning Studies*, *26*(6), 1137–1159.
Dow, D., & Larimo, J. (2011). Disentangling the roles of international experience and distance in establishment mode choice. *Management International Review*, *51*(3), 321–355.
Dyer, W., Gibb, Jr.&, & Wilkins, A. L. (1991). Better stories, not better constructs, to generate better theory: A rejoinder. *The Academy of Management Review*, *16*(3), 613–619.
Fratocchi, L., & Di Stefano, C. (2019). Do Industry 4.0 technologies matter when companies evaluate reshoring decisions? *2019 IEEE International Workshop on Metrology for Industry 4.0 and IoT, Metroind 4.0 and IoT 2019 - Proceedings*. doi:10.1109/METROI4.2019.8792897 available at.
Fratocchi, L., & Di Stefano, C. (2020). Do industry 4.0 technologies matter when companies backshore manufacturing activities? An explorative study comparing Europe and the US. In M. Bettiol, E. Di Maria, S. Micelli (Eds.), *Knowledge management and industry 4.0*. Cham: Springer. doi:10.1007/978-3-030-43589-9_3.
Friedman, T. L. (2005). *The World is Flat: A Brief History of the Twenty-First Century*. Farrar, Straus and Giroux. New York.
Frost, T., Birkinshaw, J., & Ensign, S. (2002). Centres of excellence in multinational corporations. *Strategic Management Journal*, *23*(11), 997–1018.
Gebauer, H., & Binz, Ch. (2019). Regional benefits of servitization processes: Evidence from the wind-to-energy industry. *Regional Studies*, *53*(3), 366–375. doi:10.1080/00343404.2018.1479523.
Gereffi, G., De Marchi, V., & Di Maria, E. (2017). *Local Clusters in Global Value Chains: Linking Actors and Territories Through Manufacturing and Innovation*. (Eds.), London: Routledge.
Götz, M. (2019). Unpacking the provision of the industrial commons in Industry 4.0 cluster. *Economics and Business Review*, *5*(19), 23–48.
Götz, M. (2020). Cluster role in industry 4.0 – a pilot study from Germany. Competitiveness Review, ahead-of-Print(ahead-of-print). doi: 10.1108/CR-10-2019-0091
Götz, M., & Jankowska, B. (2017). Clusters and Industry 4.0 – do they fit together? *European Planning Studies*, *25*(9), 1633–1653.
Götz, M., & Jankowska, B. (2018). On the role of clusters in fostering the Industry 4.0. In R. Van Tulder, A. Verbeke, L. Piscitello (Eds.), *International Business in the Information and Digital Age, Progress in International Business Research* (pp. 379−390). London: Emerald.
Guba, E. G., Denzin, N. K., & Lincoln, S. Y. (1994). Competing paradigms in qualitative research. (1994), In N. K. Denzin, & S. Y. Lincoln (Eds.), *"Handbook of Qualitative Research"* (1994). (pp. 105−117). Thousand Oaks, CA: Sage.
Gupta, A., & Govindrajan, V. (1991). Knowledge flows and the structure of control within multinational corporations. *The Academy of Management Review*, *16*(4), 768–792.
Harzing, A.-. W., & Noorderhaven, N. (2006). Knowledge flows in MNCs: An empirical test and extension of Gupta/Govindarajan's typology of subsidiary roles. *International Business Review*, *15*(3), 195–214.
Hermann, M., Pentek, T., & Otto, B. (2015). Design principles for Industrie 4.0 scenarios: A literature review. *Working paper no. 01*. Technische Universität Dortmund. http://www.snom.mb.tu-dortmund.de/cms/de/forschung/Arbeitsberichte/Design-Principles-for-Industrie-4_0-Scenarios.pdf.
Hervas-Oliver, J.-. L., Belussi, F., Sedita, S. R., Caloffi, A., & Gonzalez-Alcaide, G. (2020). Approaching multinationals in clusters from different perspectives. *Competitiveness Review*, *30*(4), 437–456. doi:10.1108/CR-07-2019-0071.
Hervas-Oliver, J.-. L., Estelles-Miguel, S., Mallol-Gasch, G., & Boix-Palomero, J. (2019). A place-based policy for promoting Industry 4.0: The case of the Castellon ceramic tile district. *European Planning Studies*, *27*(9), 1838–1856. doi:10.1080/09654313.2019.1642855.
Holmström, J., Holweg, M., Khajavi, S. H., & Partanen, J. (2016). The direct digital manufacturing (r)evolution: Definition of a research agenda. *Operations Management Research*, *9*(1−2), 1–10.
Jerome, L. W. (2013). Innovation in social networks: Knowledge spillover is not enough. *Knowledge Management Research & Practice*, *11*(4), 422–431. doi:10.1057/kmrp.2012.44.
Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0*. Frankfurt/Main: Acatech.
Kamp, B., & Ruiz de Apodaca, I. (2017). Are KIBS beneficial to international business performance: Evidence from the Basque Country. *Competitiveness Review*, *27*(1), 80–95. doi:10.1108/CR-07−2015−0066.
Kesidou, E., & Snijders, Ch. (2012). External knowledge and innovation performance in clusters: Empirical evidence from the uruguay software cluster. *Industry and Innovation*, *19*(5), 437–457.
Kinkel, S. (2020). Industry 4.0 and reshoring. In Lisa De Propris, & David Bailey (Eds.), *Industry 4.0 and Regional Transformations*. London: Routledge.
Kuza, K. (2018). Cluster Policy in Poland. https://www.clustercollaboration.eu/sites/default/files/event_calendar/5_katarzyna_kuza.pdf
Lafuente, E., Vaillant, Y., & Vendrell-Herrero, F. (2019). Territorial servitization and the manufacturing renaissance in knowledge-based economies. *Regional Studies*, *53* (3), 313–319. doi:10.1080/00343404.2018.1542670.
Lagendijk, A., & Lorentzen, A. (2007). Proximity, knowledge and innovation in peripheral regions. On the intersection between geographical and organizational proximity. *European Planning Studies*, *15*(4), 457–466.
Langley, A. (1999). Strategies for theorizing from process data. *The Academy of Management Review*, *24*(4), 691–710.

Lis, A. M. (2019). The significance of proximity in cluster initiatives. *Competitiveness Review: An International Business Journal*, *29*(3), 287–310.
Malmberg, A., & Power, D. (2005). (How) Do (Firms in) clusters create knowledge? *Industry and Innovation*, *12*(4), 409–431. doi:10.1080/13662710500381583.
Menzel, M. P., & Fornahl, D. (2009). Cluster life cycles-dimensions and rationales of cluster evolution. *Industrial and Corporate Change*, *19*(1), 205–238. doi:10.1093/icc/dtp036.
Morrison, A., & Rabellotti, R. (2009). Knowledge and information networks in an Italian Wine Cluster. *European Planning Studies*, *17*(7), 983–1006.
Mudambi, R., & Navarra, P. (2004). Is knowledge power? Knowledge flows, subsidiary power and rent-seeking within MNCs. *Journal of International Business Studies*, *35*(5), 385–406.
Narula, R., Asmussen, C. G., Chi, T., & Kundu, S. K. (2019). Applying and advancing internalization theory: The multinational enterprise in the twenty-first century. *Journal of International Business Studies*, *50*(8), 1231–1252.
Ortt, R., Stolwijk, C., & Punter, M. (2020). Implementing Industry 4.0: Assessing the current state. *Journal of Manufacturing Technology Management*, *31*(5), 825–836. doi:10.1108/JMTM-07-2020-0284.
Pagano, A., Carloni, E., Galvani, S., & Bocconcelli, R. (2020). The dissemination mechanisms of Industry 4.0 knowledge in traditional industrial districts: Evidence from Italy. *Competitiveness Review: An International Business Journal*, *31*(1), 27–53. doi:10.1108/CR-12-2019-0160.
Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research*, *34*(5), 1189–1208.
Pawłyszyn, I., Fertsch, M., Stachowiak, A., Pawłowski, G., & Oleśków-Szłapka, J. (2020). The model of diffusion of knowledge on industry 4.0 in marshallian clusters. *Sustainability*, *12*(9), 3815.
Pegoraro, D., De Propris, L., & Chidlow, A. (2020). De-globalisation, value chains and reshoring. In Lisa De Propris, & David Bailey (Eds.), *Industry 4.0 and Regional Transformations* (pp. 1−24). London: Routledge.
PiaFIA (2013). *The Aviation Sector in Poland*. . https://www.paih.gov.pl/files/?id_plik=21740.
Piwek, Krzysztof, K., & Wiśniowski, Witold, W. (2016). Small air Transport aircraft entry requirements evoked by FlightPath 2050. *Aircraft Engineering and Aerospace Technology: An International Journal*, *88*(2), 341–347.
Puig, F. (2019). New insights regarding clusters and industrial districts. *Competitiveness Review: An International Business Journal*, *29*(3), 206–210.
Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. et al. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. Retrived from: Http://www.inovasyon.org/pdf/bcg.perspectives_Industry.4.0_2015.pdf
Santos, J., Doz, Y. L., & Williamson, P. (2004). Is your innovation process global? *MIT Sloan Management Review*, *45*(4), 31–37. Retrieved from http://search.epnet.com/login.aspx?direct=true&db=buh&an=13758599.
Schmid, S., & Schurig, A. (2003). The development of critical capabilities in foreign subsidiaries: Disentangling the role of the subsidiary's business network. *International Business Review*, *12*(6), 755–782.
Stężycki, P., & Wiśniowski, W. (2016). Strategic alliances as an advantage in facing challenges of future aircraft engine development. *Transactions of the Institute of Aviation*, *4*(245), 338–351.
Strange, R., & Zucchella, A. (2017). Industry 4.0, global value chains and international business. *Multinational Business Review*, *25*(3), 174–184.
Sturgeon, T.J. (.2019). Upgrading strategies for the digital economy. *Global Strategy Journal*, No. October, 1−24.
Valdes, R. A., & Comendador, V. F. G. (2018). Aviation 4.0: More safety through automation and digitization. *WIT Transactions on The Built Environment*, *174*, 225–236.
Xue, J. (2018). Understanding knowledge networks and knowledge flows in high technology clusters: The role of heterogeneity of knowledge contents. *Innovation*, *20*(2), 139–163. doi:10.1080/14479338.2017.1369355.
Yamin, M., & Andersson, U. (2011). Subsidiary importance in the MNC: What role does internal embeddedness play? *International Business Review*, *20*(2), 151–162.
Yavan, N. (2010). The location choice of foreign direct investment within turkey: An empirical analysis. *European Planning Studies*, *18*(10), 1675–1705. doi:10.1080/09654313.2010.504350.
Yin, R. (2017). *Case Study Research and Applications. Design and Methods*. London: Sage Publication.
Zhang, G., Xu, Q., & Liu, X. (2011). Knowledge diffusion within the datang sock manufacturing cluster in China. *Regional Studies*, *45*(7), 977–996.