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Territorial Coupling in Industry 4.0: Assessing the Impact of Geographical Proximity to Automotive Industry on the Digital Entrepreneurs in Poland

Authors:

1. Associate Prof. Dr. Krzysztof Gwosdz (Corresponding Author)
Email: krzysztof.gwosdz@uj.edu.pl
Institution: Jagiellonian University
2. Dr. Marcin Baron
Email: marcin.baron@uekat.pl
Institution: University of Economics in Katowice
3. Prof. Marcin Budka
Email: mbudka@bournemouth.ac.uk
Institution: Bournemouth University
4. Associate Prof. Dr. Mariusz Hetmańczyk
Email: mariusz.hetmanczyk@fppp.gov.pl
Institution: Silesian University of Technology
5. Dr. Agnieszka Sobala-Gwosdz
Email: asobala-gwosdz@irmir.pl
Institution: Institute for Regional and Urban Development
6. Dr. Ing. Robert Szczepanek
Email: robert.szczepanek@uj.edu.pl
Institution: Jagiellonian University

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Abstract: There is a vibrant debate within the fields of economic geography and regional studies regarding the mechanisms of industrial upgrading and the creation of new developmental paths. This debate has recently been enriched by discussions on the transformative role of Industry 4.0 (I4.0). A substantial portion of the research dedicated to I4.0 focuses on its demand side, examining the readiness and adoption of I4.0 technologies in manufacturing firms. However, the role of firms that provide services and products aligned with I4.0, referred to here as 'digital entrepreneurs', has not been as extensively explored. Given that the automotive industry is at the forefront of adopting novel digital technologies, this article examines, using Poland as a case study, the extent to which geographic proximity to automotive clients is indispensable for the emergence and development of digital entrepreneurs. To achieve this objective, we employ a comprehensive set of methodologies, ranging from geostatistical analyses, questionnaire surveys, and in-depth interviews, to network analyses of managerial flows. Our findings reveal that the strength of territorial coupling varies across different types of digital entrepreneurs, contingent on the specific nature of the solutions they provide. Empirically, our study corroborates the existence of a locational dichotomy between IT-related and production-related Industry 4.0 technologies. Referring to the literature discussing various types of locations for high-tech services and digital entrepreneurs, our research predominantly supports the incubation hypothesis, which posits that such enterprises are more likely to be found in large metropolitan centres. Conversely, the restructuring hypothesis appears to be applicable only to a very limited number of industrial, medium-sized towns with a strong industrial base

Keywords: Industry 4.0 Technology Providers, Automotive Industry, Geographical Proximity, Path Creation, Interpath Relationship, Restructuring of Industrial Regions, Central and Eastern Europe, Poland

Introduction

The ongoing debate within the economic geography and regional studies has been dynamically engaged with unpacking the mechanisms underpinning the creation of new developmental trajectories (Martin & Sunley 2015; Isaksen & Jakobsen 2017; Hassink et al. 2019). This discourse has recently witnessed a substantive enrichment, stemming from deliberations on the transformative implications of Industry 4.0 (Szalavetz 2017; De Propris & Bellandi 2021). Notably, the automotive sector has been identified as a pioneering industry in the adoption of novel digital technologies, positioning itself at the vanguard of this technological revolution (Manello and Calabrese, 2015, Drahoukoupil J. 2020). Industry 4.0 is perceived as an ongoing epochal transformation, fundamentally reshaping the automotive industry (Covarrubias & Ramirez Perez, 2020: 19). This is underscored by projections indicating a substantial increase in IT spending within the automotive sector while the ascendancy of the electric car revolution is providing a fertile ground for start-ups and innovations, facilitating their integration into emergent supply chains.

In the context of this evolving landscape, our research seeks to address a three gaps in the existing literature. Firstly, there is a discernible tendency in extant studies to primarily scrutinise the demand side of Industry 4.0, often to the detriment of adequately considering the transformative power of supply side, i.e. technology and service providers for the I4.0.

(referred further in the article as the digital entrepreneurs after Szalavets 2020). Secondly, the predominant focus at the regional level (NUTS2), with an over-reliance on patent data, has resulted in a paucity of insights into the nuanced intra-regional variations, particularly pronounced in Central and Eastern European countries, where the patenting activity is significantly smaller than in the core countries of the developed world. Thirdly, the transformative impact of digital entrepreneurs remains an underexplored terrain, with existing research largely confined to qualitative analyses of relatively small samples of entrepreneurs (Szalavets 2020).

In response to these lacunae, our research is framed by two pivotal questions: To what extent is geographic proximity to automotive clients indispensable for the emergence and development of digital entrepreneurs? Furthermore, does the co-location of automotive customers and digital entrepreneurs play a significant role in catalysing the emergence of new pathways in industrialized regions? Through addressing these questions, our study aims to contribute to a more holistic understanding of the interplay between geographic proximity, industrial evolution, and entrepreneurial innovation within the context of the fourth industrial revolution. Poland, along with other Central and Eastern European countries, representing an intermediate position in the global division of labour between core and peripheries, serves as a particularly intriguing area for such analysis.

Theoretical Framework and Review of the Literature

In this chapter, we delve into the theoretical foundations of new path development and creation, with a particular focus on inter-path relationships and the role of geographical proximity. We aim to elucidate how these elements interact and influence the trajectory of industrial evolution at the local and regional level, especially in the context of Industry 4.0.

The concept of path-creation has gained substantial popularity in evolutionary economic geography. In a broad sense, a new path can be understood as the emergence and growth of new industries and economic activities in regions (MacKinnon et al., 2019, p. 113). In a narrower perspective, new path creation is perceived as the most radical form of new path development, encompassing the introduction of radical new products or services (Simmie et al., 2008; Isaksen et al., 2019). The sources of a new path include both intended and unintended results of actions undertaken by economic agents or institutions. There exists an extensive body of literature aimed at elucidating the mechanisms of path creation. In particular, debates revolve around endogenous versus exogenous factors of new path creation (e.g., Mörner and Trippel 2019, Frangenheim et al., 2020, Grillitsch & Sotarauta, 2020), as well as the role of industrial relatedness (Neffke et al., 2011). For instance, Boschma and Frenken (2018) argue that new paths tend to emerge more frequently in regions that rely more on related variety than unrelated variety.

In light of the objective of our work, a pivotal question regarding the relationships between emerging industrial paths, or inter-path linkages, becomes essential. This can be encapsulated in the question - How does the development of a new industry in a region affect other emerging industries within the same region? Micek et al. (2022), in organizing the existing literature, note that inter-path relationships are examined from two perspectives – diachronic and synchronic. The former deals with how established paths impact the development of new paths and pertains to classic studies within the concept of path dependence. It is highlighted in the literature that historically formed characteristics of a place can create an “enabling” or “restricting” environment for new industries (e.g., Martin 2010). The second point relates to interactions

between simultaneously developing new paths. According to Frangenheim et al. (2020), three main types of synchronous relationships can be distinguished: competitive, neutral, and supportive. Frangenheim et al. (2020) persuade, that the robustness of linkages between distinct paths is tied to the extent to which they are dependent upon identical or divergent markets, as well as upon their shared or unique access to assets and resources, whether they are scarce or plentiful. In reference to the classic literature on path-dependence, another mechanism worth emphasizing is a critical juncture (Mahoney 2000), which occurs when there is an intersection of previously independent industrial paths, potentially leading to lasting effects in the form of the emergence of a new path. This is particularly pertinent in the context of Industry 4.0. Some researchers suggest that the revolutionary nature of Industry 4.0 technologies lies not so much in the radical novelty of the technologies per se, but rather in the unprecedented convergence of fairly disparate technological fields within a short period, resulting in a new quality (e.g., Chiarello et al., 2018; Kogler, 2021).

In the context of inter-path relationships, it is crucial to examine the role of proximity. For several decades, there has been an ongoing discussion in the literature about the role of proximity in local and regional development processes, including its impact on knowledge flows, innovation, financial condition of enterprises, and the emergence of new companies. Five types of proximity are most commonly distinguished: social, institutional, organisational, cognitive and geographical (Boschma 2005), with the latter being of particular interest to us due to the topic at hand. As G. Micek (2017) notes in a comprehensive literature review, there is a significant dispute over the role of geographical proximity in innovative processes, with the spectrum of researchers' views ranging from denying its importance to acknowledging its key role. Proponents of the significant importance of geographical proximity argue that it increases the likelihood of inter-firm relationships (e.g., Grosetti 2008), although this depends on various factors including the industry and the life cycle stage of the company. In high-tech sectors, the importance of geographical proximity has been observed to be significant in the aerospace sector (Levy and Talbot 2015, Micek 2017), pharmaceutical sector (Abramovski and Simpson 2011), but less so in the IT sector (Weterings 2006). Nonetheless, even studies of IT companies show that geographical proximity is important, as it provides the opportunity for frequent contact with customers, leading to greater flexibility (Matuschewski 2002, cited in Micek 2017). Tözün (2009), based on the software services for the automotive industry in the Stuttgart region, demonstrates that the presence of a geographical agglomeration of automotive customers is a reason for specialized software firms to locate near existing industrial clusters. In the automotive industry, the significance of proximity has been proven to be particularly important in the initial phase of implementing new, collaborative innovative projects (Schamp et al. 2004). In the original methodological study by Ciappei and Caloffi (2023), the authors demonstrate that there is a colocation between the location of technology-KIBS involved in 4.0 activities in Italy and their proximity to manufacturers utilizing 4.0 technologies.

Empirical studies of European regions conducted by Balland and Boschma (2021), as well as Capello and Lenzi (2021), have revealed significant disparities among different areas in their potential to develop new paths based on clusters of Industry 4.0 technology suppliers. Balland and Boschma (2021) have identified two distinct subsystems thus far: one centered around IT technologies (computer-related I4.0) and the other focused on manufacturing technologies (manufacturing-related I4.0). The fact that as many as twenty out of twenty-six “emerging technologically regions” (also referred to as innovation islands) in Europe are directly adjacent to regions that were already known as high-tech industry hubs underscores the role of geographical proximity to leaders and the potential strength of growth spillover effects from these poles. Adler and Florida (2021) point to three types of places or “niches” that can foster

the emergence of P4.0 technology concentrations: leading tech hubs, major global cities, and areas of traditional industry.

Corradini et al. (2021) provide evidence that individual P4.0 technologies vary in their requirements for the existence of sector-specific (specialised) capabilities. For example, technologies associated with robotics and additive manufacturing (3D printing) demonstrate a strong inclination towards locational factors, which are possessed by only a few industrial regions, whereas Industrial Internet of Things (IIoT) and big data technologies can be developed in a larger number of locations. As Corradini et al. (2021) emphasize, the ability of individual territories to generate innovations related to P4.0 should simultaneously take into account factors related to the characteristics of a given area, as well as technological factors associated with the specificities of individual P4.0 solutions. This aligns well with the observation by Balland and Boschma (2021, p. 1661) that "there is no single geography of Industry 4.0 in Europe".

Research design

In the initial phase of the research, a geostatistical analysis was undertaken to examine the spatial distribution of automotive and digital entrepreneurs. To facilitate this, two comprehensive databases were established: the first encompassing 823 automotive plants, and the second comprising 1000 digital entrepreneurs. The automotive database included not only entities statistically classified as vehicle and parts manufacturers (NACE 29), but also manufacturers from other sectors that derived at least 25% of their revenue from the automotive market. Identification of the latter was based on possession of the IATF 16949 certification. Knowledge about digital entrepreneurs was extracted from a variety of dispersed information sources, primarily patent databases, specialized company directories published by leading industry journals related to automation, robotics, and information technologies, as well as websites of technology parks, special economic zones, clusters, and industry associations. While the automotive database captures the vast majority of firms and facilities (excluding small companies manufacturing for the aftermarket), the completeness of the digital entrepreneurs database should be interpreted in such a way that it is likely the most comprehensive database of such firms in Poland, but does not cover the entire set of entities. The number of digital entrepreneurs can only be estimated, as there is no their official statistical classification.

A questionnaire survey, administered through CATI/CAWI methods, was directed towards the latter, yielding responses from 150 firms. The questionnaire survey facilitated the identification of characteristics, the localisation factors, and the distribution of markets for digital entrepreneurs. This research was conducted between October and December 2022. Additionally, a secondary survey was conducted amongst 23 Owners/CEOs of automotive companies, all of whom are members of a leading cluster initiative, in April 2022.

The study was further enriched by 30 in-depth interviews (IDIs) with managers from both the digital and automotive sectors, as well as key informants, unveiling the underlying mechanisms of their interactions.

In order to confirm the hypothesis of territorial coupling of the automotive industry with their suppliers we have used a network analysis approach (Wassermann & Faust 1994). This was made by a pilot study, focusing on the industrial hub of Bielsko-Biała, known for its concentration of automotive and digital entrepreneurs, allowed for a nuanced analysis of these managerial positions flows and relationships. A network (or graph) is a mathematical representation of a collection of interconnected entities (nodes) through various relationships

or connections (edges or links) (Gross et. al 2018). In our setting, the nodes of the network represent businesses characterised by their primary NACE code (4 digit), while the edges correspond with current or past personnel links (e.g., the same person appointed to be a Board member in both organisations). Hence, we use the movement of the managerial personnel between organisations as a proxy for a commercial relationship, which is one of the limitations of our study imposed by data availability. The dataset we have used comes from National Courts Register and spans a 21-year period between 2001 and 2022. Following the famous “6 degrees of separation” principle (Karinthy, 1929) we quantify the affinity of two NACE codes by the distribution/histograms of the shortest path lengths between organisations from the corresponding NACE codes. We focus on NACE 29 (automotive) and examine the similarity of intra (i.e., NACE 29 with itself) and inter (i.e., NACE 29 with other NACEs) connectivity pattern. We use the Wasserstein (earth mover’s) distance metric to calculate the similarity between two discrete distributions.

Results

Geography of automotive vs geography of digital entrepreneurs

We shall commence our analysis by providing a succinct presentation of the relationships between the distribution of automotive industry and the geography of digital entrepreneurs. The automotive industry in Poland, which has primarily been shaped by the locational decisions of foreign companies over the last three decades, is currently concentrated mainly in the south-western part of the country (Fig. 1). This concentration is largely attributed to the general orientation of Polish manufacturing towards West European markets. Four NUTS2 regions—Śląskie (PL22), Dolnośląskie (PL51), Wielkopolskie (PL41), and Podkarpackie (PL32)—account for 68% of employment in the industry. The main centre of the automotive industry in Poland is Śląskie, particularly the towns of Gliwice, Tychy, Bielsko-Biała, and Częstochowa, alongside the adjacent Krakow Metropolitan Area in Malopolskie (PL21), which boasts a diverse supplier base and relatively strong non-production functions, including R&D (Domański and Gwosdz, 2018). The Wielkopolska region plays a significant role, primarily due to the engagement of the Volkswagen Group. The Dolnośląskie has emerged as a primary beneficiary in attracting foreign subsidiaries of automotive suppliers, a success attributed to the A4 motorway corridor and proximity to the borders with Germany and the Czech Republic. Industrial traditions, skilled workforce, infrastructure, and special incentives in economic zones significantly influence the location of new plants in Podkarpackie, the only eastern region with a significant current presence of the automotive industry.

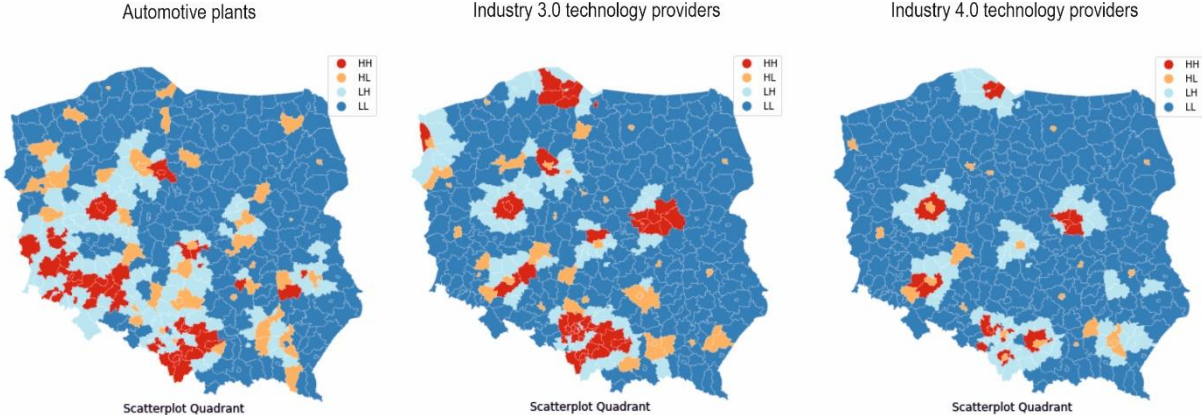


Fig. 1. Geostatistical Analysis - Areas of Concentration for Automotive, 4.0 Technology

Suppliers (Digital Entrepreneurs), and 3.0 Technology Suppliers (Automation and Robotics) in Poland

Source: Own research

The regions with the highest concentration of digital entrepreneurs in Industry 4.0, accounting for a combined 68% at the national level, are mazowieckie (PL12), śląskie, dolnośląskie and małopolskie. Within the regions, digital entrepreneurs exhibit a strong concentration in a limited number of cities and counties, predominantly in the hot-spots of core cities of Poland's largest metropolises (Fig. 1). Three-quarters of the identified digital entrepreneurs are located within the seven largest metropolises in Poland, with nearly a quarter in the capital metropolitan area of Warsaw alone. Nevertheless, in comparison to all high-tech services, certain metropolitan areas and regional cities in southern Poland, such as the GZ Metropolis in Śląskie and Rzeszów (Podkarpackie), demonstrate an elevated position. This may reflect the influence of proximity to local and regional sales markets, fostered by medium-high tech (especially the automotive industry) and high-tech (aviation industry) companies. This is illustrated by the correlation coefficients at the NUTS2 level, with a value of 0.64 between the share of digital entrepreneurs and GDP, significantly lower than the analogous relationship with Gross Value Added in industry at 0.76.

Digital entrepreneurs constitute a highly heterogeneous set, reflecting the diversity of services, products, and solutions pertinent to Industry 4.0. In the NACE classification of economic activities, they are dispersed across various categories (see, for example, Fassio and Nathan 2020). Literature commonly identifies two main groups within this sector: IT-focused firms and those embedded in production technologies (Balland and Boschma, 2021). We propose the delineation of at least a third group—technology integrators—most commonly classified under NACE section 33. The strength of the co-location relationship between various types of digital entrepreneurs and the automotive industry varies significantly at the regional (NUTS2) level (Fig. 2). It ranges from very low for IT-related DI4.0 (determination coefficient $R^2 = 0.1232$), to low for Automotive vs Production Related DI 4.0 ($R^2 = 0.2295$), and high for Automotive vs Integrators DI4.0 ($R^2 = 0,6748$). The control variable (integrators vs the entire manufacturing industry) demonstrated a significantly weaker relationship ($R^2 = 0.2061$), suggesting that the co-occurrence of integrators and automotive firms is not coincidental. This hypothesis is further corroborated by the insights gleaned from our in-depth interviews, affirming the existence of this relationship as discussed later in the article.

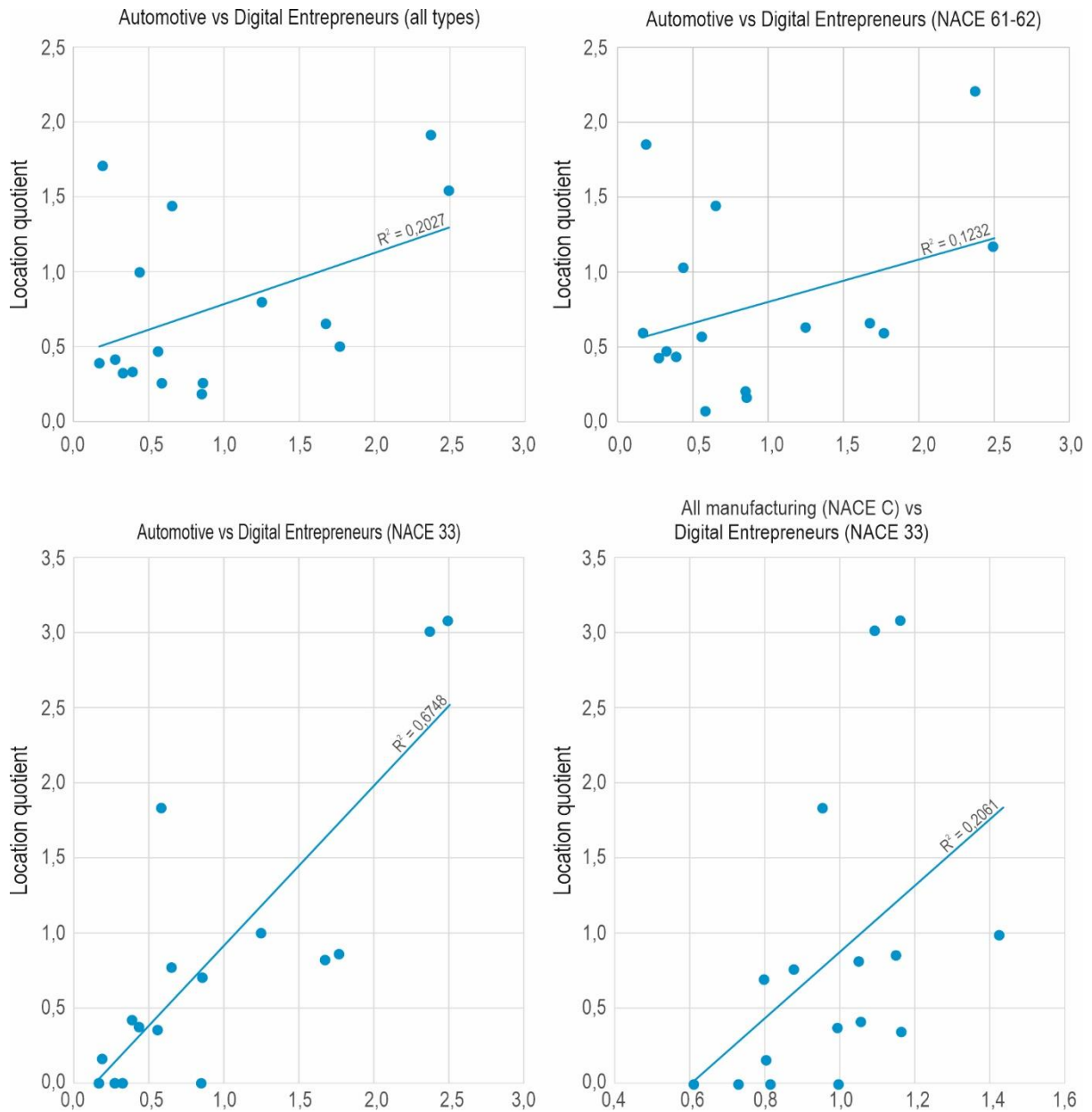


Fig. 2. Correlation Analysis (at NUTS2 level) Between the Location of Different Types of Digital Entrepreneurs and Manufacturing Plants Serving the Automotive Industry

Source: Own research

Location Determinants of Digital Entrepreneurs: A Survey Study

Before discussing the results concerning the location factors and cooperation of digital entrepreneurs with their industrial clients, a brief characterisation of the surveyed population is necessary. The overwhelming majority of digital entrepreneurs are companies with domestic (Polish) capital (80%). The largest number of respondents (43%) started their operations in the past 15 years. Almost equal proportions of the sample employ 1–9 people, 10–49 people, and 50–249 people (each group at about 30%). Only 9% of respondents employ 250 or more individuals. For 60% of those surveyed, over half of their revenue comes from clients within the industrial sectors. The primary recipients of their products and services are large and

medium-sized companies, with 53% and 39% of mentions, respectively. Companies most frequently offer traditional IT solutions, often bundled as complementary products or technologies. The next group comprises products based on specific systems (e.g., 3D printing and scanning, VR/AR, robots/cobots). The least commonly offered solutions are those unique to a smaller range of applications or characterised by significant market entry barriers.

The digital entrepreneurs deem the bandwidth of internet connections and the availability of specialised staff as crucial for the operation and the development of their competitive edge in their current locations, rating them 3.4 and 3.3 respectively on a scale of 1-4. The proximity to firms from other industries, which are potential clients, was deemed relatively unimportant, scoring a 2.1

In terms of trade relations, based on the value of orders/supplies, the companies most frequently identify the entire country as the location of their key clients. Territorial proximity is of less significance, though for respondents from regions with a large number of identified digital entrepreneurs, the regional environment appears to be important. Regional sales markets account for 17% of the market, while local markets are virtually insignificant (see Fig. 3). 18% of respondents have located their branches near major clients in Poland, and 10% plan to do so within the next two years. Additionally, 15% of the surveyed companies have branches/offices abroad, near major clients, and 10% anticipate adopting this form of internationalisation in a two-year perspective. Beyond client proximity, digital entrepreneurs also seek to benefit from the agglomeration effects of being situated in clusters of high-tech innovative firms. 44% of respondents offer solutions specific to particular industrial sectors, while 56% deal with solutions applicable across various industrial and service sectors. No statistically significant difference was observed between these groups in terms of the market, nor were there any statistically significant differences identified between the location of the market and the industrial sector's share in revenues.

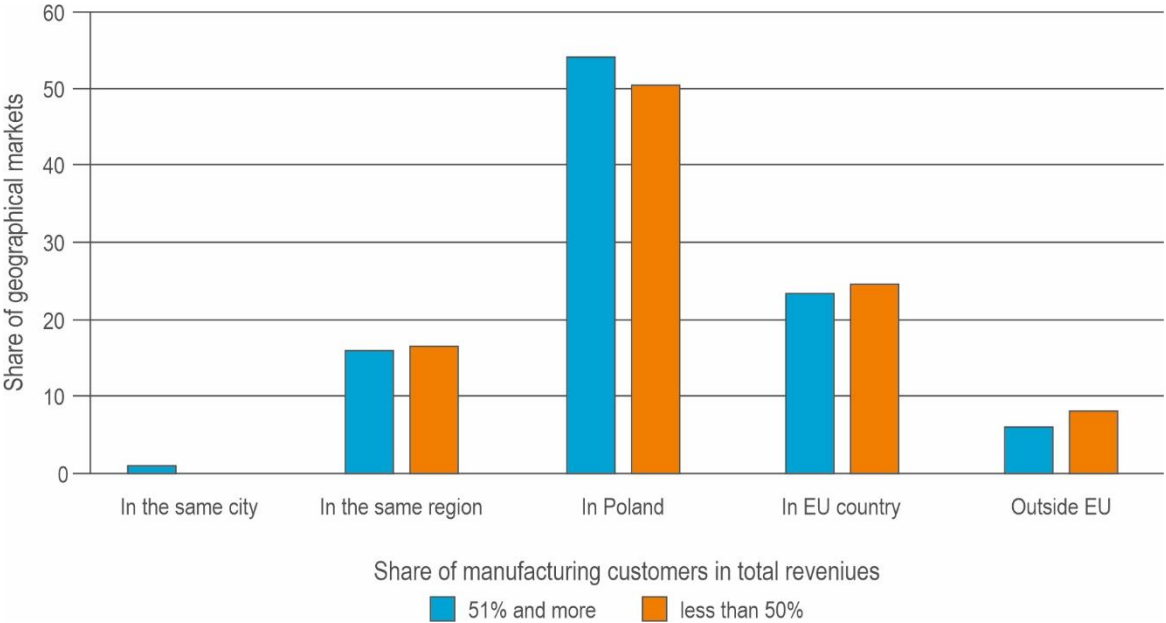


Fig. 3. The principal geographical markets for digital entrepreneurs

Source: Own research (survey n=150 companies)

The results obtained from the survey of digital entrepreneurs align with the responses from the managers of automotive companies. Both groups, those who have already implemented Industry 4.0 technologies in their companies and those planning to do so in the near future, indicate that their main partners in implementation are companies located in Poland. However, the role of regional suppliers is relatively small, accounting for 10% and 20%, respectively. Similar to the digital entrepreneurs, the factors influencing the implementation of Industry 4.0 technologies at the current location for automotive companies are primarily 1) Proximity of Qualified Staff, followed by 2) Access to Broadband Internet. The Educational Offer Targeting I4.0 was rated relatively highly, and as the fourth most important factor, the managers highlighted the proximity of I4.0 Suppliers. Engineering firms offering system integration and implementation are emphasised as the most significant partners in implementing 4.0 technologies (70%), followed by representatives of well-known IT/technology brands (52%). It is noteworthy that, in the perception of both digital entrepreneurs and automotive companies, there is a modest role for cooperation with clusters or other business environment institutions.

Discussion of mechanism behind territorial coupling

The conducted analysis of the co-occurrence of automotive manufacturers and digital entrepreneurs has identified five areas characterized by a particularly high concentration of both types of activities (Wrocław, Poznań, Gliwice, Tychy, and Bielsko-Biała). Functionally, these are the cores of supra-regional metropolises—Poznań, Wrocław—or centers of polycentric metropolises, GZM (Górnośląski Związek Metropolitalny) – Gliwice and Tychy in GZM. Only Bielsko-Biała has a non-metropolitan character. Each of these cities is currently the location for final assembly manufacturers (Tychy and Gliwice for Stellantis, Poznań for VW and Solaris, Wrocław for Volvo Bus), with the exception of Bielsko-Biała. However, historically, Bielsko-Biała hosted a passenger car assembly plant, on the basis of which, following transformations, companies belonging to the Fiat group established their Polish branches producing parts or modules. Do these co-locations merely represent a co-occurrence of the studied sectors (unrelated variety), or are they the result of inter-path relationships that could lead to the emergence of a critical juncture and a new, dynamic development path? These questions were addressed through in-depth interviews, which revealed several mechanisms that can lead to territorial coupling of the studied industries at the local and regional levels.

The proximity to large automotive manufacturers implies potential proximity to significant customers. For digital entrepreneurs, an ‘anchor’ in the form of a first major client (or sometimes even a direct spinoff from a large company) is fundamentally crucial. Only thereafter can markets be expanded. However, local and regional cooperative connections do not automatically establish themselves. Since leading automotive firms are typically local branches of foreign corporations, the possibility of cooperating with local companies is determined by the level of autonomy in choosing suppliers, the demand for specific Industry 4.0 solutions, and the capability of local suppliers to meet these demands. Broader conditions for such cooperation have emerged relatively recently, necessitating a certain maturation of both industries. One of the catalysts was a radical change in the labour market that occurred after 2015, necessitating accelerated automation and robotization of factories. A particular role is played by final assembly manufacturers, who attract collaborators offering 4.0 solutions to their factories and the supplier parks located nearby (e.g., Volkswagen in Poznań, Września, and Swarzędz). Nonetheless, it has been observed that a local supplier typically means "a supplier located in the nearest metropolitan centre." Geographic proximity (travel time) is significant, as many processes require frequent contact.

The initiation or reinforcement of relationships between the sectors under study resulted from the growing activity of business environment institutions, including the establishment of new organizations focused on such activities. Some special economic zones, technology parks, and cluster structures have become the entities driving this change. It is noteworthy that in most areas, such a proactive policy, especially acceleration programs, has only emerged in Poland in the last decade. These initiatives have been built upon earlier factors, such as government incentives (Special Economic Zones), locational features (mainly the western and south-western parts of the country, regional and local industrial traditions, good connections with the network of fast roads). Only later – and not everywhere – have regional ecosystems and pro-innovation policies started to develop on top of these, with a strong current expectation for key FDI players to open up to organizing R&D activities around their Polish locations. A particular example of such initiatives is the Silesia Automotive and Advanced Manufacturing Cluster Initiative, which is directly aimed at connecting technology suppliers and clients from industrial companies, especially in the automotive sector. The special role of the automotive industry stems both from the fact that this sector is a leader in implementing Industry 4.0 solutions and from its large scale presence in Poland. Acceleration programs conducted by leading Polish technology parks (including those in Wrocław, Kraków, and Gliwice) contribute to the accelerated development of technology suppliers offering digital solutions (e.g., the hub4industry program implemented in the Kraków Technology Park).

Local inter-industry flows of managerial staff represent another mechanism facilitating the interaction between sectors. An analysis of network connections among managerial staff conducted by the authors in Bielsko-Biała demonstrated that particularly close ties characterize the automotive sector and companies involved in machine installation (including integrators) (Fig. 4). This confirms that this type of digital entrepreneurs is most strongly locally connected to the automotive industry. The role of staff mobility within the region was also noted as a mechanism accelerating the implementation of 4.0 solutions.

The spin-off mechanism is another significant factor. Some of today's leading providers of 4.0 technology in Poland emerged from individuals who previously worked in automotive factories. When they recognized an opportunity to supply equipment themselves, they established their own businesses. They identified a niche for starting their own business and already had established cooperation with equipment suppliers who had delivered to their previous factories. At the same time, their former colleagues, who had become directors in these factories, facilitated the acquisition of contracts.

The automotive company itself can become a digital entrepreneur through the development of competencies in this area. This is related, among other things, to the rapidly growing role of IT in the industry (Winkelhake 2022). In surveys conducted among companies in the sector, nearly one in five CEOs/owners declared that they already are manufacturers/suppliers of Industry 4.0 technology. Large R&D centres operating in the industry (including those in Wrocław, Kraków, Katowice) and recent declarations to open new centres, largely IT-based (including Stellantis in Gliwice, IAV in Wrocław), may also become another significant source of spin-offs.

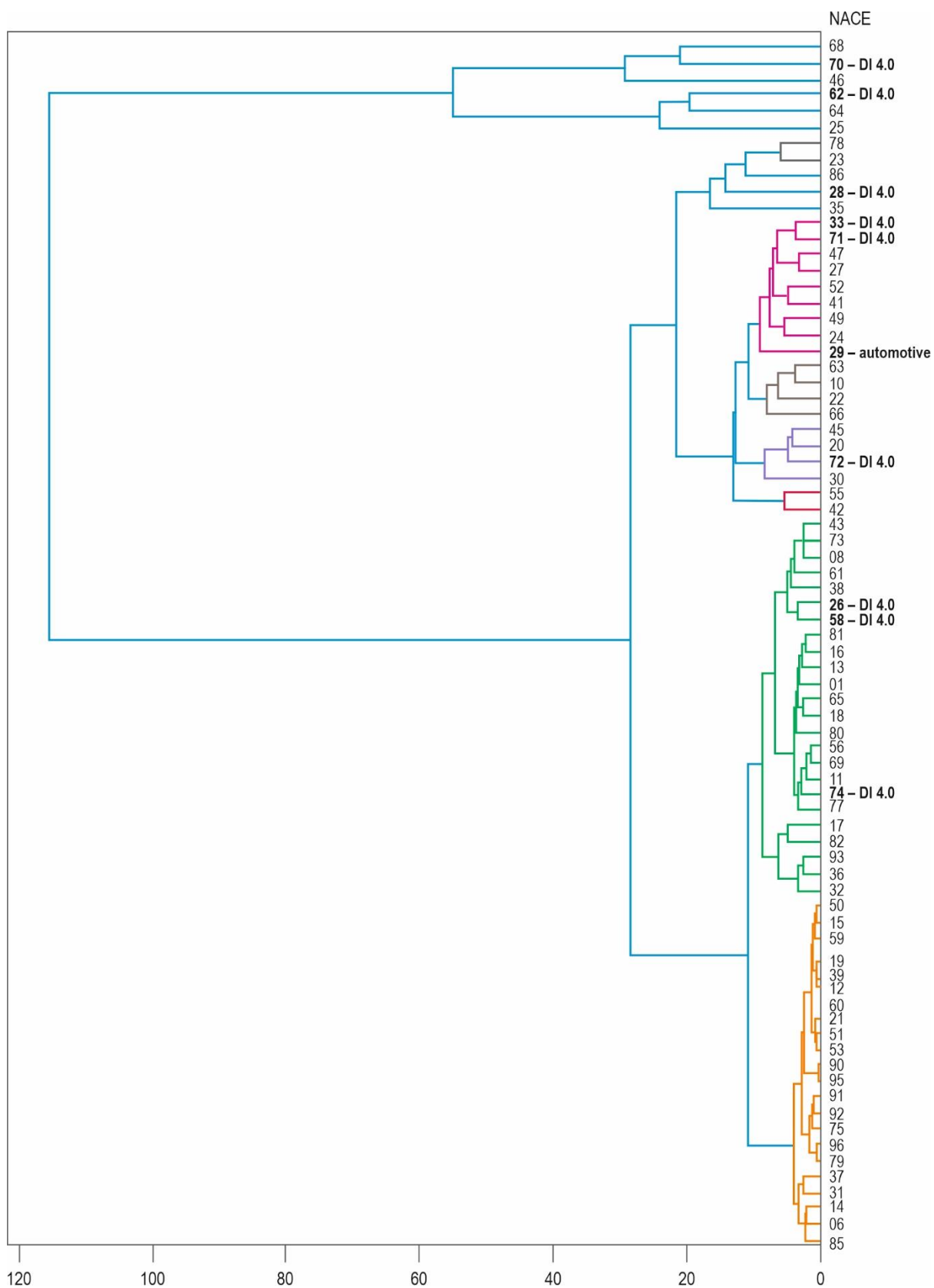


Fig 4. NACE groupings based on unnormalised histogram connection pattern similarity with NACE 29 (automotive). The case of Bielsko-Biala

Source: Own research based on National Court Register Data on companies

Conclusions

In their 2021 study, Balland & Boschma highlighted the necessity to delve more profoundly into the fields of economic application of Industry 4.0 Technologies (I4Ts) in regions, emphasizing potential synergies between the locations of technology production and industrial application of I4T. Our article responds to this call by examining the level of co-occurrence and mechanisms of coupling between automotive manufacturers and Industry 4.0 technology providers.

The territorial coupling strength varies among different types of digital entrepreneurs, depending on the nature of the solutions they offer. Empirical evidence has confirmed a dichotomy in locational factors between IT-related and production-related I.4.0 technologies. The former is strongly linked to major metropolitan centres, while the latter has greater potential for development also in certain non-metropolitan areas.

Undoubtedly, the automotive sector plays a significant role in attracting companies offering solutions in system integration, robotics, and automation. The main mechanisms driving this include the importance of proximity to the customer (for flexibility and response time) and spin-offs from the automotive industry. However, not every significant concentration of automotive manufacturers possesses such pull. The fact that significant agglomerations of digital entrepreneurs mainly include metropolitan cities and large urban centres, with limited extension to smaller cities under 150-200 thousand inhabitants, indicates that the presence of automotive industry clients is not a sufficient condition. Digital entrepreneurs mainly emerge in cities equipped with a strong technical university, a diversified economy, and robust innovation support centres. Thus, fertile ground for digital entrepreneurs is found in centres where proximity to customers intertwines with a certain minimum level of metropolitan characteristics. This observation aligns with the insights provided by Horváth and Rabetino (2019), who argue that ‘manufacturing specialization alone is insufficient’ to attract knowledge-intensive business services.

Referring to the discussed literature on types of locations for advanced activities and digital entrepreneurs (see Benko 1991, Adler and Florida, 2021), our findings lend more support to the incubation hypothesis (location in large metropolitan centres), while the restructuring hypothesis applies only to some industrial, more to post-industrial metropolises (in Poland, the Silesian Metropolis, to a lesser extent Łódź) than to medium-sized industrial cities.

Among non-metropolitan automotive production clusters, areas with a large number of diversified clients and a few locations where one major entity (lead firm) has established itself, especially if it has a campus-like nature with several related plants operating, may have some potential to initiate a new developmental path. In such places, at least in the near future, digital entrepreneurs are likely to be an enriching element of local economic diversification rather than a significant driving force. An intriguing question is whether we will observe a hierarchical diffusion of digital entrepreneurs, as was the case with suppliers of Industry 3.0 technologies (automation), or rather a persistence of disparities between main metropolitan centres – industrial region hubs – and other areas, which may not be able to create significant clusters of Industry 4.0 technology providers.

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