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BARRIERS TO DIGITAL TRANSFORMATION OF HIGH AND MEDIUM HIGH TECH GLOBAL MANUFACTURING ENTERPRISES IN POLAND

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Abstract. The aim of the study is to identify the key barriers to digital transformation and assess the structure of interrelations between these barriers and the selected characteristics of enterprises, their approach to digital transformation, as well as the technological advancement of products in large and very large foreign manufacturing enterprises operating in the high and medium high technology sectors in Poland. The empirical research is based on information from 95 survey respondents. Multidimensional correspondence analysis was applied in the research to simultaneously assess the structure of interrelations between the categories of multiple nominal variables. The conducted research shows that more than 50% of the surveyed enterprises indicated excessive costs of digitalization as the main barrier to its implementation, followed by uncertain market conditions and lack of own financial resources. The most significant difficulties related to the implementation of digitalization were primarily experienced by the enterprises operating in Poland for up to 10 years, free to relocate, not committed to develop innovative products, and presenting negative approach to digital transformation. The research findings provide crucial information useful for businesses, politicians, researchers and technology providers in creating more effective strategies and policies to support the Industry 4.0 development. It can contribute to increased business competitiveness and innovation, thus having a positive impact on the economy in general. The article constitutes an original study based on the authors' own research.

Keywords: digitalization, barriers to industrial digitalization, technological advancement of products, high and medium high technology sector enterprises, Poland, multivariate correspondence analysis.

JEL Classification: C39, C63, D81, O31.

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1. Introduction

To remain competitive in the face of globalization and stringent environmental regulations, leading manufacturers of industrial products are adopting digital technologies. This shift allows implementing new processes across the entire value chain, from production and sales to service provision. Consequently, global industry leaders are actively digitizing key functions within their internal vertical value chains, integrating them with horizontal supply chain partners, enhancing their product offerings with digital capabilities, and introducing innovative services based on digital data (Hakhovych et al., 2024, p. 72). Hence, advanced digital technologies constitute a critical component of digital transformation. They are at the core of the socio-economic disruptions caused by the emergence of digitally enhanced business models that enable defragmentation of the global value chains in which multinational enterprises operate. Many studies have addressed technological elements of this phenomenon, such as, e.g., additive manufacturing, cloud computing, connectivity, robotics and automation, big data and manufacturing analytics, artificial intelligence, digital twins, and Model-Based Enterprise (MBE) environments (Johnes et al., 2021, p. 938). Digital potential is present at every stage along the value chain in various ways and to different degrees (Bogner et al., 2016, p. 15). It allows enterprises to create unique customer experiences, offer new products and services, and utilize their resources in a more efficient manner through new combinations of information, human capital, and technological solutions (Łobejko, 2018, p. 644). Digitalization is not a mere transition from "analog" to digital data and documents, it constitutes a network of business processes, such as building effective interfaces, integrating data exchange and management.

Following an extensive literature review and semantic analysis, G. Vial developed a working definition of digital transformation, calling it "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" (Vial, 2019, pp. 120–121). It rests on a fundamental change process enabled by digital technologies, which brings radical improvement and innovation to an entity and creates value for its stakeholders by strategically leveraging its key resources and capabilities (Gong & Ribiere, 2021, p. 10). This results in scale reorganization of the whole business model (Gobble 2018, p. 57). The COVID-19 pandemic is perceived to have facilitated digital transformation of enterprises, however, rapid development also faces significant barriers such as limited staff competences and lack of financial resources, which impede acquiring new technologies and investing in restructuring business processes. It is essential to identify barriers to digital transformation first, to be able to reduce their negative impact (Uzule & Verina, 2023, p. 126), although they vary across different types of industries and organizations (Packmohr et al., 2023, p. 103; Bharadwaj, 2000, pp. 170-176).

The aim of the study was to identify the key barriers to digital transformation and assess the structure of interrelations between these barriers and the selected attributes of large and very large foreign manufacturing enterprises operating in high and medium high technology sectors in Poland, their approach to digital transformation, as well as the technological advancement of the goods they produce. Previous literature has acknowledged the innovation potential of new digital technologies for the manufacturing sector, however, little is known about how its players should manage their digital innovation processes (Abrell et al., 2016). The literature review conducted by Kutnjak revealed that most research papers related to barriers to digital transformation focused on education and public sectors, and only several of them addressed the manufacturing industry. They identified 440 potential difficulties faced by organizations when implementing digital solutions (Kutnjak, 2021, pp. 79377–79378). Moreover, the issue of barriers to digital transformation was mostly addressed from the perspective of small and medium-sized enterprises (Johannesson et al., 2023; Omowole et al., 2024; Packmohr et al., 2023), as well as companies operating in traditional industries (Warner & Wäger, 2019). Large enterprises are hypothesized to experience lower barriers to digital transformation as they operate with greater budgets and more abundant resources than small and medium-sized companies. Nonetheless, a comparative study between the two types of organizations indicated the opposite (Johannesson et al., 2023, p. 82; Packmohr et al., 2023, pp. 115–116). Narrowing the research scope down to emphasize specific sectors and industries was, therefore, expected to generate more insight into the origin and structure of these difficulties.

To achieve the above objectives, the following research questions were formulated:

1. Which barriers to digitalization are considered the key ones by large and very large foreign high and medium high-tech enterprises operating in Poland?
2. Which barriers to digitalization differentiate foreign enterprises the most considering their characteristics, the level of technological advancement of products and approach to digital transformation?
3. Which characteristics of enterprises are most related to the identified barriers to digitalization?
4. How does the technological advancement of products affect the encountered barriers to digitalization?
5. How does the enterprise approach to digital transformation affect the encountered barriers?

2. Theoretical background

As a result of enterprise digital transformation, and an increase in the socio-economic digital maturity, the so-called Industry 4.0 was created (Śledziewska & Włoch, 2020, p. 81). This concept, prevalent in the manufacturing sector, is presented in Figure 1. The development of Industry 4.0 involves integrating physical elements, such as objects, people, machines, and production lines with virtual reality in a manner that transcends the boundaries of traditional operations and connects them into an intelligent and agile value chain (Schumacher et al., 2016, p. 162). Thus, Industry 4.0 integrates the digital to physical world using cyber-physical systems and human-machine interface to increase productivity and efficiency. This enables real-time synchronization of production processes to fulfil customer demands for unitary or personalized products, as well as ensures efficient, individualized, and cost-effective production using smart machines, smart sensors, and other computer-based technologies (Kumar et al., 2021, p. 85).

Industry 4.0 is defined as the readiness to absorb technology and the ability to swiftly adapt to changes occurring in the digital economy (Aslanova & Kulichkina, 2020, p. 444). Its fundamental components include:

- implementation of a digital strategy, which presents the company's clear vision and understanding of the purpose and goals of digitalization,
- selection of digital technologies to improve business processes and supply chain efficiency, agility, and sustainability,
- management of the technological, operational, and organizational changes that constitute the digital transformation process,

Figure 1. Interdependence between digitalization, digital transformation, and Industry 4.0 (source: original work, based on Pokorska, 2023, p. 33)

- support for the workforce to embrace the digital transformation and enhance their digital skills,
- continuous and efficient data management for learning and maximizing the results of digital transformation.

The pace of technological developments transpiring into business practice has resulted in digitalization becoming widespread and widely appreciated for the convenience and utility it brings to organizations in various economic sectors. Not surprisingly, digital technologies are often seen as general-purpose technologies that improve efficiency and effectiveness across industries (Trittin-Ulbrich et al., 2020, p. 10). The COVID-19 pandemic has certainly "pushed" digital transformation into certain areas of business activity, so that organizations should now take advantage of the opportunities and power offered by the digital world with all the technology that facilitates and enables the execution of work processes (Kutnjak, 2021, p. 79384). However, digitalization is also a wicked challenge that does not have one solution, one set of rules, or even one desired outcome (Johnes et al., 2021, p. 936). Major interventions into the organization's properties are required when implementing it. This means that radically altering business models and structures to leverage new technology is neither simple nor straightforward. Digital transformation involves stepping out of the comfort zone and possibly eliminating practices that employees and customers have come to expect or even taken for granted. It causes enterprises to rethink the very foundation of who and what they are (Saariko et al., 2020, p. 826).

The number and type of barriers to digital transformation vary significantly across the existing source literature (Borangiu et al., 2019; Calabrese et al., 2020; Kamble et al., 2018; Kiraz et al., 2020; Lammers et al., 2019; Mahmood et al., 2019; Nambisan et al., 2019; Raj et al., 2020; Saariko et al., 2020; Stentoft et al., 2021; Tripathi & Gupta, 2019; Vogelsang et al., 2019), as well as across the industries that were investigated, i.e.: banking (Diener & Špaček, 2021), financial services (Chanias et al., 2019), construction (Chen et al., 2024; Linderoth et al., 2018), higher education (Gkrimpizi et al., 2023) and public services (Tangi et al., 2020). However, several so-called significant barriers to Industry 4.0 adoption were identified. They are as follows (Kumar et al., 2021, p. 86; Senna et al., 2022, pp. 3–4):

- poor value-chain integration to create cyber-physical infrastructure,
- cyber-security challenges,
- uncertainty about economic benefits of capital investment in digitalization,
- lack of adequate skills in workforce,
- high investment requirements due to lack of funds,
- absence of infrastructure (internet coverage, IT infrastructure),

- job disruptions (fear of labour market shifting the structure of existing jobs),
- challenges in data management and data quality (low capability of handling large amount of data and extracting valuable information from their large volume),
- lack of secure standards and norms,
- resistance to change from employees.

Moreover, Jones et al. selected three top barriers to digital transformation in manufacturing sector, as reported in six separate major articles addressing the problem. In Figure 2 they are categorized in a rank order of significance or the greatest difficulty to overcome (Johnes et al., 2021, p. 938).

It seems that most of the barriers in the manufacturing sector relate to technical and technological difficulties, insufficiently qualified employees (and their reluctance to accept the digital change), lack of financial resources, inappropriate legal regulations, or the risk of digital value chain integration. Missing skills were even identified as the central barrier to digital transformation for the manufacturing companies (Vogelsang et al., 2019, p. 4941). Other emphasized challenges relate to the lack of effective digitalization strategies and the need to replace obsolete technology with the latest solutions, which requires incurring further costly investments. Hence, there is a persistent doubt regarding the clarity of the actual economic benefits offered by digitalization. Focusing on the manufacturing sector in Russia, Lola and Bakeev divided the barriers to digital transformation into five categories based on the absence or scarcity of: budget, infrastructure, competence, payback and conditions (Lola & Bakeev, 2020, p. 7).

Firm size plays an important role in the adoption of digital technologies. In the European Union the size effect is particularly pronounced among manufacturing firms. Only 30% of companies with fewer than ten employees adopted digital technologies, whereas this share amounts to 79% for enterprises with more than 250 employees (Rückert et al., 2020).

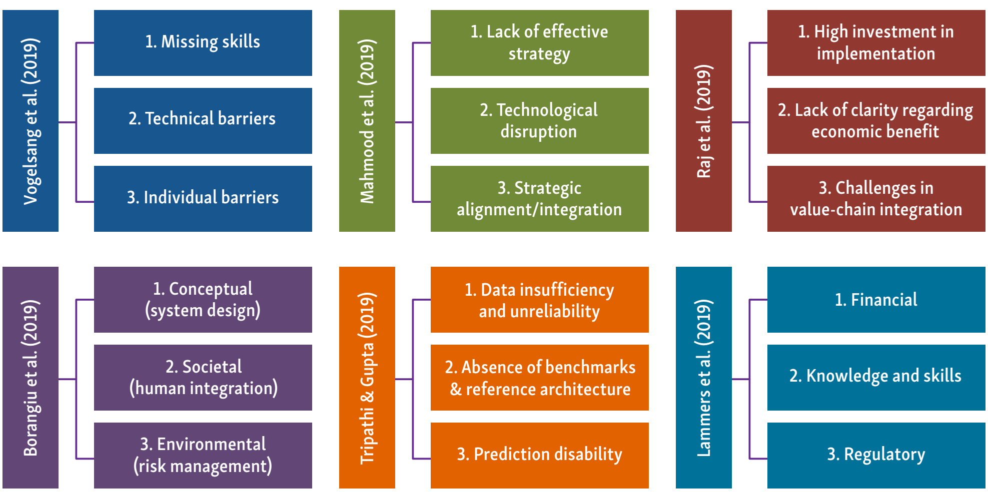

Figure 2. Major barriers to digital transformation in manufacturing according to various studies. Each illustration shows the top three barriers as listed and described in the relevant article (source: Johnes et al., 2021, p. 939)

Large enterprises are at the forefront of digital transformation. The value of the Industry 4.0 Development Index, measuring the digital intensity of twenty-seven EU member states, is above the EU's average for large enterprises and ranks the country 11-th. The Index value for small and medium-sized companies remains at quite a low and immature level, placing Poland on a distant 23-rd position (Pokorska, 2023, p. 169). Large enterprises, and large foreign enterprises in particular, are the most familiar with the Industry 4.0 advancements and generate the biggest share of demand for digital technologies (Grzyb, 2019b, p. 256). At the same time, companies with foreign capital make up 42% of large enterprises in Poland and are responsible for approx. half (49%) of their employment (Główny Urząd Statystyczny, 2020, Tables 4 and 7). They adopt digital technologies in response to the increasing complexity of products and services, distributed manufacturing processes, and growing expectations from customers and business partners worldwide. For this reason, agility and efficiency along the global value chain are essential to remain competitive in the disruptive international landscape.

Previous literature on barriers to digital transformation has focused primarily on identifying the types of existing barriers and addressing the challenges faced by small enterprises, which often lag behind medium-sized and large enterprises. In the European Union, only 30% of micro firms took steps to improve digitalization in 2022, compared to 62% of large companies (European Investment Bank, 2023, p. 2). However, according to the Boston Consulting Group report presenting the research covering 70 leading companies worldwide, only 30% of digital transformations met or exceeded their target value and resulted in sustainable change. Approx. 44% created some value, however, did not meet their targets and resulted in limited long-term change only, while 26% created limited value (less than the target of 50%), producing no sustainable change. Taking a comparative perspective, successful transformations created, on average, 66% more value, improved corporate capabilities by 82%, and met 120% more of their targets on time than those who failed (Forth et al., 2020, pp. 4–5). Large multinational enterprises seem to be struggling to implement digital technologies, even though at the same time they stand at the forefront of the digital change. Being steps ahead of the SMEs, they experience not only the benefits, but also the challenges of digitalization. This paradox seems ever more relevant for Poland which, in the past decades, relied its economic development on the inflow of large direct foreign investments.

Company competitiveness will become a function of digital maturity, which itself could be driven by various motives depending on own resources, sector characteristics and value chain relationships with partners (Götz & Jankowska, 2020, p. 75). To achieve this, special attention should be paid to mitigating barriers to digital transformation, however, first they need to be structured and well understood by the decision makers in countries such as Poland, which aspire to play the ever greater and higher value-added role in the global manufacturing ecosystem. Also, despite the abundance of previous literature reviews and investigations aimed at identifying enterprise barriers to digital transformation, there is a significant research gap in addressing the interrelations of these barriers with specific business characteristics, which we aimed to bridge.

3. Materials and methodology

Our research was focused on high and medium high tech manufacturing industries as they contribute to economic growth and development at both the national and international levels. They foster technological progress in the economy, intensify competition among enterprises, continuously improve the quality parameters of goods and services, and increase the demand for technically advanced products (Raczyk & Dobrowolska-Kaniewska, 2009, p. 43). The research aimed at identifying the key barriers to industrial digitalization in Poland and linking them with the selected attributes of foreign companies operating in high and medium high tech manufacturing industries. The study covered large or very large enterprises operating in Poland, primarily focused on the production of high or medium high technology, owned by foreign entities holding at least 10% of ordinary shares (share in capital) or entitled to 10% votes at the general meeting of stockholders/shareholders, not listed on the Warsaw Stock Exchange.

Orbis database was the source of statistical information about the analysed enterprise cohort, providing information on over 360 million companies from all countries worldwide. The companies, where the dominant entity was an investor from Poland, or which did not perform production activities in Poland were removed from the search results. In accordance with Orbis database, that large enterprises meet at least one of the following criteria:

- employment size of 150 people or more;
- annual turnover equal to or higher than EUR 10 million;
- annual balance sheet total equal to or higher than EUR 20 million.

Similarly, the class of very large enterprises was distinguished, meeting at least one of the following conditions:

- employment size of 1000 people or more;
- annual turnover equal to or higher than EUR 100 million;
- annual balance sheet total equal to or higher than EUR 200 million.

After applying the adopted criteria, based on the Orbis database, the size of the general population amounted to 618 large and very large foreign enterprises operating in Poland. The use of social media allowed reaching out to all of them, which ensured a random sample selection. The total of 95 correctly completed questionnaire forms were collected, which constituted 15% of the general population.

To ensure the statistical significance of the results, the minimum required sample size was determined for a large population meeting the specified accuracy requirements (Cochran, 1977, p. 75; Aczel, 2000; Kot et al., 2007; Mider & Marcinkowska, 2013). Based on the adopted parameters: a significance level of $\alpha = 0.1$, an estimation error $d = 0.1$, and an estimated proportion of the population presenting the specified characteristic $p = 0.1$, the minimum required sample size, for which the basic estimation accuracy requirements are met, was 68 (according to the calculations available in Pokorska (2023, p. 141)). Exceeding the minimum required sample size enhances the reliability of the results, enables more precise inferences about the entire population, and, in the context of statistical significance, indicates that the analysis results are highly likely to be representative of the studied population. Therefore, it can be concluded that the random sample of 95 elements is representative of the population of large and very large foreign enterprises in Poland operating in technology-intensive manufacturing industries. The research material was collected using the diagnostic survey method and applying the survey technique. The time scope of the research covered 2020.

Due to the thematic scope, the potential survey respondents were board members, general directors, strategic and operational directors, managers and unit heads supervising production processes and their digitalization, or engineers and specialists responsible for the implementation of digital solutions in the company.

The respondents were asked for their opinion regarding the main barriers to investing in the digital transformation in Poland. The survey questionnaire included seven main barriers to digital transformation faced by the surveyed enterprises and the possibility of indicating their absence (yes, no responses). Due to the multitude of potential challenges related to digitalization, their purpose was to represent all five categories of barriers referential for the manufacturing industry (as in Lola & Bakeev, 2020, p. 7):

B_1 – excessive implementation costs (budget);
B_2 – uncertain market conditions (conditions);
B_3 – lack of own financial resources (budget);
B_4 – limited access to investment incentives (conditions);
B_5 – lack of skilled workforce (competences);
B_6 – lack of information on actual benefits (payback);
B_7 – limited availability of local partners (infrastructure).

The respondents were also asked to answer three groups of questions concerning general characteristics of the enterprise (variables X_1–X_5), technological advancement of products (variables X_6–X_8), and approach to digital transformation (variables X_9–X_{11}). The description of the variables used in the study, along with the set of possible answers and their corresponding codes, is presented in Table 1.

Table 1. Description of the variables used in the study, the response options available to the respondents, and the used codes (source: authors' compilation)

Variable	Description	Responses	Codes
General characteristics of the enterprise			
X_1	Type of industry	aerospace	x1: Aero
		chemical and pharmaceutical	x1: Ch&Ph
		electronics and electrical engineering	x1: Elec
		machinery	x1: Mach
		automotive	x1: Moto
		other[1]	x1: Other
X_2	Position in the supply chain	OEM – original equipment manufacturer	x2: OEM
		TIER 1 – direct supplier to the manufacturer	x2: Tier 1
		TIER 2 – subcontractor for the direct supplier	x2: Tier 2
		TIER 3 – subcontractor for another subcontractor	x2: Tier 3

[1] Industries: precision, renewable energy, manufacture of medical and optical equipment and apparatus, manufacture of other transport equipment excluding ships and boats, manufacture of electric drives and electric vehicle charging stations.

End of Table 1

Variable	Description	Responses	Codes
X_3	Period of operation in Poland	from 5 to 10 years	x3: from 5 to 10y
		less than 5 years	x3: less than 5y
		more than 10 years	x3: more than 10y
X_4	Concern about relocation to another country	maybe	x4: Maybe
		no	x4: No
		yes	x4: Yes
X_5	Planning further development in Poland	maybe	x5: Maybe
		no	x5: No
		yes	x5: Yes
Technological advancement of products			
X_6	Product innovation	companies offering products in line with the actual market demand and trends	x6. Accurate
		companies offering cutting-edge technology products that are ahead of their competitors.	x6: Hi-Tech
		companies offering products are outdated and should better address market trends.	x6: Old
X_7	Launch of a new/improved product in the last 3 years	no	x7: No
		yes	x7: Yes
X_8	Have a 3-year smart product implementation plan	no	x8: No
		yes	x8: Yes
Approach to digital transformation			
X_9	Implementation of digitalization in the last 3 years	no	x9: No
		yes	x9: Yes
X_{10}	Importance of digital transformation for the company	moderately important – digital transformation is recognized as relevant but competes with other strategic priorities.	x10: M_important
		not important – digital transformation is not prioritized in strategic planning or investment.	x10: N_important
		very important – digital transformation is a key strategic priority, reflected in resource allocation and top-management focus.	x10: V_important
X_{11}	Have a global digitalization strategy	no	x11: No
		yes	x11: Yes

Multiple Correspondence Analysis (MCA) was applied to a dataset that contains nominal outcomes (variables) for all companies. Multiple correspondence analysis is an extension of a well-known Correspondence Analysis (CA), and allows analysing patterns of relationships between several categorical dependent variables (Hirschfeld, 1935). MCA can also be perceived as a generalization of the principal component analysis, where variables are categorical rather than quantitative (numerical) (Abdi & Valentin, 2007, p. 651). Each nominal variable has several levels, and each level is coded as a binary variable (either 1 or 0). Both correspondence analysis and multiple correspondence analysis are descriptive multivariate techniques for exploring the associations inherent to multiple-choice questions. The paper by Nishisato (2006) shows an extensive overview of both methods. The main assumption for multiple correspondence analysis is that data must be non-negative, besides that this method does not need any assumptions on distributions (Clausen, 1998, p. V). The main limitation is that the CA has been shown to have limiting cases of unweighted and weighted log-ratio analysis (the latter also known as the spectral map) (Greenacre, 2010, p. 613).

The key assumptions and limitations of the MCA are shown in the Appendix A of this paper.

MCA codes the data by creating several binary columns for each variable with the constraint that one and only one of the columns gets the value 1. Such coding scheme creates artificial (dummy) additional dimensions because one categorical variable is coded with several columns. As the result, the inertia (i.e., variance) of the solution space is artificially inflated and the percentage of inertia explained by the first dimension is underestimated (Abdi & Valentin, 2007).

Let's suppose there are n observations on p categorical variables. Let's assume q_j different values for variable j. Next, matrix $\mathbf{G}_j$ is defined, which is $n \times q$ matrix. This matrix is known as indicator matrix. The $n \times q_j$ matrix $\mathbf{G}$ with g the sum of q_j can be obtained by concatenating the $\mathbf{G}_j$'s (Greenacre 2017). In general, MCA can be defined as the application of weighted principal component analysis where indicator matrix is used as input (Benzécri, 1973). The indicator matrix is divided by its grand total (np) to obtain the correspondence matrix $\mathbf{F} = \frac{1}{np}\mathbf{G}$ The vectors $\mathbf{r} = \mathbf{F1}_q$ and $\mathbf{c} = \mathbf{F}^{\mathrm{T}}\mathbf{1}_n$ are the row and column marginals. These marginal are the vectors of row and column masses. Suppose the diagonal matrices of the masses be defined as $\mathbf{D}_r = diag(\mathbf{r})$ and $\mathbf{D}_c = diag(\mathbf{c})$.

MCA can be defined as the application of PCA to the cantered matrix $\mathbf{D}_r^{-1} = (\mathbf{F} - \mathbf{rc}^{\mathrm{t}})$ with distances between profiles given by chi-squared metric defined by $\mathbf{D}_c^{-1}$. The n projected coordinates of the row profiles on the principal axes are called row principal coordinates. The $n \times k$ matrix $\mathbf{X}$ of row principal coordinates is defined by $\mathbf{X} = \mathbf{D}_r^{-1/2}\tilde{\mathbf{F}}\mathbf{V}$ and $\mathbf{V}_k$ is the $q \times k$ matrix of eigenvectors corresponding to k largest eigenvalues $(\lambda_1, \lambda_2, \ldots, \lambda_k)$ of the matrix $\tilde{\mathbf{F}}'\tilde{\mathbf{F}}$**.** The projected row profiles can be plotted in different planes defined by these principal axes called row principal axes (Greenacre & Blasius, 2006).

Column profile categories can be descried by column profiles. The value can be calculated by dividing the columns of $\mathbf{F}$ by their column marginals. Interchanging rows with columns and all associated entities can be used for dual analysis of column profiles. This is done by transposing matrix $\mathbf{F}$ and repeating all the steps. The metrics used to define the principal axes of the cantered profile matrix $\mathbf{D}_r^{-1/2}(\mathbf{F} - \mathbf{rc}^{\mathrm{t}})^{\mathrm{t}}$ are $\mathbf{D}^c$ and $\mathbf{D}_r^{-1}$. The $q \times k$ matrix $\mathbf{Y}$ of column principal coordinates is defined as $\mathbf{Y} = \mathbf{D}_c^{-1/2}\tilde{\mathbf{F}}^t\mathbf{U}_k$, where $\mathbf{U}_k$ is the $n \times k$ matrix of eigenvectors corresponding to the k largest eigenvalues $\left(\lambda_1, \lambda_2, \ldots, \lambda_k\right)$ of matrix $\tilde{\mathbf{F}}\tilde{\mathbf{F}}^t$. In order to assist visualization and interpretation by principal axes, which are known as column principal, planes can be plotted (Johnson & Wichern, 2007).

The absolute contribution of the j-th variable to the inertia of column principal component α is the α-th column of **Y** defined as $c_{j\alpha} = \sum_{s \in M_j} s \in M_j f_{.s} y_{s\alpha}^2$, where M_j is the set of categories of the j-th variable. The relation between the absolute contribution $c_{j\alpha}$ and the correlation ratio between variable j and the row standard component is given by $\eta_{j\alpha}^2 = \sum_{s \in M_j} \frac{n_s}{n}\left(\bar{x}^* - D\right)^2 = p \times c_{j\alpha}$.

For more information on correspondence analysis and multiple correspondence analysis see, e.g., Johnson and Wichern (2007), Greenacre and Blasius (2006), Le Roux and Rouanet (2010), Hjellbrekke (2018).

The research was carried out in accordance with the procedure described below, consisting of the following steps:

- step I: identification of the main barriers to industrial digitalization based on the survey research.

Each subsequent stage of the research procedure involves identifying the structure of interrelations of all industrial barriers to digital transformation (B_1–B_7) with a selected group of variables describing the enterprise:

- step II: variables determining the general characteristics of the enterprise (X_1–X_5);
- step III: variables describing the technological advancement of products (X_6–X_8);
- step IV: variables representing the approach to digital transformation (X_9–X_{11}).

Steps II to IV were preceded by examining whether the variables are dependent using chi-squared tests. Then the occurrence of a relationship between barriers to digitalization (B1–B7) and different groups of characteristics of the surveyed companies was verified.

The applied research procedure allowed assessing the diverse structure of interrelations between barriers to digital transformation and different activity areas of the surveyed enterprises. The research focused on coordinates, quality of mapping, the contribution of categories to the formation of dimension and perceptual maps.

The details of calculations made in the correspondence analysis and multivariate correspondence analysis can be found in many papers, e.g., Benzécri (1973), Greenacre and Blasius (2006), Abdi and Valentin (2007), Le Roux and Rouanet (2010), Greenacre (2017).

The package ca for R software (Greenacre et al., 2020) and ca function were used to obtain the final results.

4. Results of the research

By including the full population of enterprises in the survey, the absence of arbitrary selection and the possibility of free participation in the survey ensured the sample randomness. The survey covered all large and very large manufacturing enterprises with foreign capital, operating in the medium high and high technology sectors in Poland, identified in the ORCID database (618 companies) and the decision to complete the survey questionnaire was taken solely by the companies.

The survey research covering a sample of high and medium high tech global manufacturing enterprises in Poland, presenting their opinions on the main barriers to investing in digital transformation in Poland, are shown in Figure 3.

Before applying multivariate correspondence analysis, the independence of variables in each group was tested using the chi-squared test of independence. The relevant calculations are included in Tables B1–B4 in Appendix B: Results of chi-squared test of independence (p-values). The analysis of the data in Tables B1–B4 shows that for a significance level of $\alpha = 0.05$, there is no basis to reject the null hypothesis about the independence of tested variables. In all cases, p-value ≥ 0.05.

Next, the relationship between barriers to digitalization (B_1–B_7) and the particular groups of characteristics regarding the surveyed companies, i.e., variables determining the general characteristics of the enterprise (X_1–X_5), technological advancement of products (X_6–X_8) and representing the approach to digital transformation (X_9–X_{11}), was examined using the chi-squared test of independence. In the case of general company characteristics, the p-value was 0.0004998, which means the occurrence of a relationship between company characteristics and barriers to digitalization. For variables describing the technological advancement of products, p-value of = 2e-04 was calculated, which indicates that also in this case a relationship between these variables and barriers to digitalization is present. Regarding the approach to digitalization, p-value of = 2.2e-16 was obtained, also confirming the relationship between the approach to digitalization and barriers. The findings justify the use of multivariate correspondence analysis, as they prove the co-occurrence of the analysed categories of digitalization barriers and the variables according to the particular groups.

The use of correspondence analysis allowed presenting multivariate data in the form of two-dimensional perceptual maps (Figures 4–6). The position of individual points on the perceptual map in each case informs about the average position of barriers to digitalization identified by the surveyed enterprises (B1–B7) and, respectively, general characteristics of the

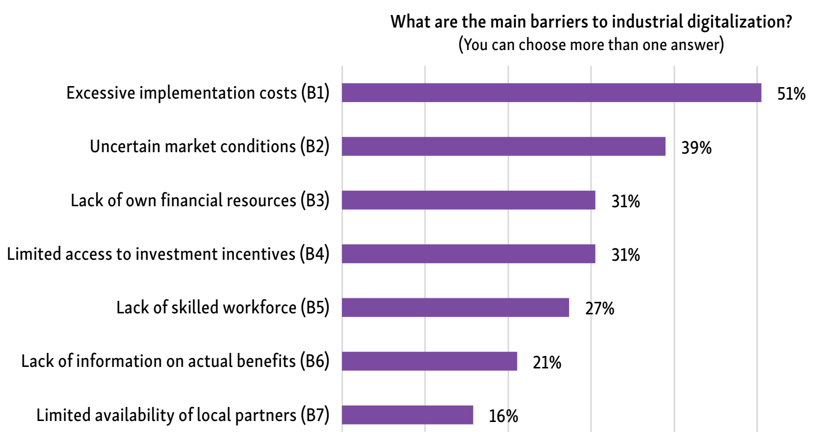

Figure 3. Main barriers to industrial digitalization based on the survey research (source: authors' computation)

enterprise (variables X1–X5), technological advancement of products (variables X6–X8), and approach to digital transformation (variables X9–X11). Interpretation of the perceptual map involves assessing:

1. the position of the points relative to the centre of the coordinate system – the points close to the intersection of the axes represent the categories of barriers to digitalization and variables typical of the surveyed companies, not showing uniqueness due to the substantive importance assigned to the dimensions, and the outermost categories as clearly different from the others;
2. the position of a given point relative to other points representing categories of the same or another variable – a close position indicates frequent co-occurrence of categories.

Visualization of the research results in two-dimensional space, owing to its simplified form, facilitates the identification of key barriers to digitalization and the interpretation of the complex structure regarding the relationship between barriers to digitalization and the analysed variables. For each of the two dimensions, percentages were determined to explain total inertia. Total inertia is a measure of spread of the points (categories of digitalization barriers and variables) in the actual multidimensional space. The share of total inertia is a measure to assess the importance of individual dimensions in explaining the structure of the relationship between barriers to digitalization and the general characteristics of the enterprise, technological advancement of products and approach to digital transformation. The two dimensions explaining the largest portion of inertia, and therefore the most significant for the results of the analysis, were included in the study. The dimensions were assumed to be significant if their contribution to the total inertia exceeds 10%, and both dimensions combined at least 40%. Assigning substantive meaning to the dimensions in correspondence analysis is crucial for interpreting the results and formulating conclusions, as it allows identifying the main differentiation areas and observing how the various barriers and variables interact. It requires not only a thorough interpretation of perceptual maps, but also a detailed analysis of the coordinates of variable categories and barriers to digital transformation, characteristics of the quality of mapping real relationships in two-dimensional space, and the contribution of categories to the formation of dimensions.

Perceptual map is a helpful and widely used tool for visualizing the correspondence analysis results, but it provides only an estimate of the position of points in the coordinate system. Specifying the exact coordinate values of axes 1 and 2 allows determining accurately the location of individual points representing categories of digitalization barriers and variables analysed in two-dimensional space.

The quality of mapping categories (squared correlations) by the first or second dimension (glt1, qlt2) enable assessing the quality of mapping of each digitalization barrier category and also the general characteristics of the enterprise, technological advancement of products and approach to digital transformation by the first and second dimensions, respectively. High values of quality indicators inform about a strong relationship of a specific category with the corresponding dimension. When a category has a high-quality mapping to a dimension, it means that its position on the perceptual map reflects accurately its relationship to that dimension.

The contribution of categories to the formation of the first or second dimension (ctr1, ctr2) allows assessing the importance of the impact of each category in shaping a particular dimension.

The results of the relevant calculations taking into account the listed characteristics obtained using multivariate correspondence analysis are shown in Tables 2–4. Detailed interpretations and analyses of the findings following the application of multivariate correspondence analysis are presented in the Discussion section.

The results of the second stage of the research procedure are presented in Figure 4, which shows all the considered barriers (B_1 to B_7) to digitalization and variables X_1 to X_5 – general company characteristics, where additional numbers or characters after a dot simultaneously represent the levels. The first dimension allows for 32.1% of total inertia. The second one 12.0% of total inertia.

The coordinates of variable categories and barriers to digital transformation, characteristics of the quality of real relationships mapping in two-dimensional space, and the contribution of categories to the formation of dimensions are shown in Table 2.

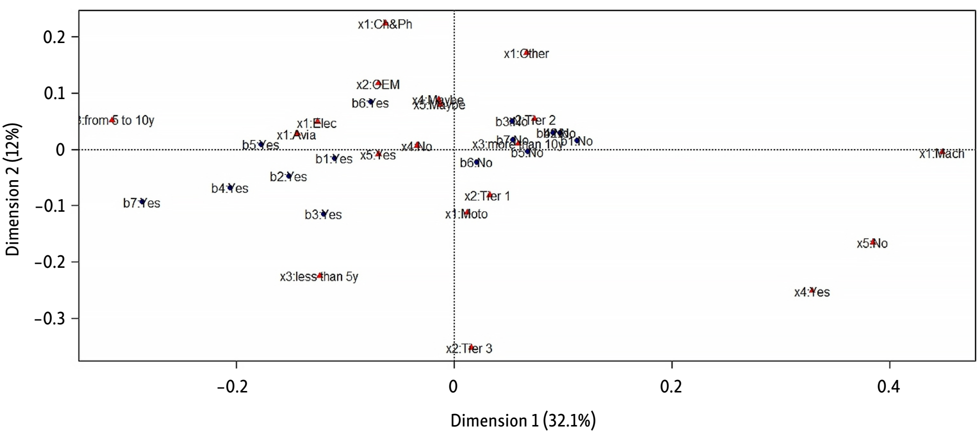

Figure 4. General company characteristics (variables X_1 to X_5) and barriers to industrial digitalization (source: authors' computation based on R results)

Table 2. The results of multivariate correspondence analysis for general company characteristics (variables X_1 to X_5) and barriers to industrial digitalization (source: authors' computation with R software)

Categories of variables and barriers	Coordinates		Quality of category mapping by dimension			Contribution of categories to the dimension formation	
	axis 1	axis 2	(1) + (2) qlt	(1) qlt1	(2) qlt2	ctr1	ctr2
x1: Aero	–0.144	0.028	0.150	0.145	0.005	0.016	0.002
x1: Ch&Ph	–0.063	0.223	0.538	0.040	0.497	0.003	0.102
x1: Elec	–0.126	0.049	0.336	0.292	0.044	0.017	0.007
x1: Mach	0.448	–0.006	0.641	0.641	0.000	0.098	0.000
x1: Moto	0.012	–0.112	0.399	0.004	0.394	0.000	0.101

End of Table 2

Categories of variables and barriers	Coordinates		Quality of category mapping by dimension			Contribution of categories to the dimension formation	
	axis 1	axis 2	(1) + (2) qlt	(1) qlt1	(2) qlt2	ctr1	ctr2
x1: Other	0.066	0.171	0.146	0.019	0.127	0.002	0.044
x2: OEM	–0.070	0.117	0.487	0.129	0.358	0.012	0.089
x2: Tier 1	0.032	–0.082	0.339	0.046	0.293	0.003	0.052
x2: Tier 2	0.073	0.053	0.178	0.116	0.062	0.005	0.007
x2: Tier 3	0.016	–0.352	0.320	0.001	0.319	0.000	0.092
x3: from 5 to 10y	–0.314	0.051	0.450	0.438	0.011	0.083	0.006
x3: less than 5y	–0.124	–0.225	0.340	0.079	0.261	0.006	0.057
x3: more than 10y	0.059	0.010	0.539	0.524	0.014	0.018	0.001
x4: Maybe	–0.014	0.087	0.131	0.003	0.128	0.000	0.026
x4: No	–0.034	0.006	0.237	0.230	0.008	0.006	0.001
x4: Yes	0.329	–0.251	0.636	0.402	0.234	0.060	0.094
x5: Maybe	–0.013	0.079	0.167	0.004	0.163	0.000	0.034
x5: No	0.384	–0.165	0.586	0.495	0.091	0.113	0.056
x5: Yes	–0.070	–0.009	0.267	0.262	0.004	0.019	0.001
b1: No	0.112	0.016	0.463	0.453	0.009	0.041	0.002
b1: Yes	–0.110	–0.016	0.463	0.453	0.009	0.040	0.002
b2: No	0.097	0.030	0.534	0.487	0.047	0.038	0.010
b2: Yes	–0.152	–0.047	0.534	0.487	0.047	0.060	0.015
b3: No	0.053	0.050	0.383	0.201	0.183	0.013	0.031
b3: Yes	–0.120	–0.114	0.383	0.201	0.183	0.029	0.071
b4: No	0.090	0.030	0.644	0.581	0.063	0.038	0.011
b4: Yes	–0.206	–0.068	0.644	0.581	0.063	0.086	0.025
b5: No	0.067	–0.003	0.453	0.452	0.001	0.022	0.000
b5: Yes	–0.178	0.009	0.453	0.452	0.001	0.057	0.000
b6: No	0.021	–0.022	0.250	0.114	0.136	0.002	0.007
b6: Yes	–0.077	0.084	0.250	0.114	0.136	0.008	0.027
b7: No	0.054	0.017	0.633	0.573	0.06	0.016	0.005
b7: Yes	–0.287	–0.093	0.633	0.573	0.06	0.086	0.024
Sum	X	X	X	X	X	1.000	1.000

Notes: qlt – the quality of representation; glt1, qlt2 – the quality of category mapping by the first or second dimension (squared correlations), respectively; ctr1, ctr2 – the contribution of categories to the formation of the first or second dimension, respectively.

Variables X_6 to X_8 describing the company product, and all barriers were analysed as a separate subset of dataset. The results are shown in Figure 5.

The first dimension allows for 41.7% of total inertia, the second one for 15.4% of total inertia. The results of multivariate correspondence analysis are shown in Table 3.

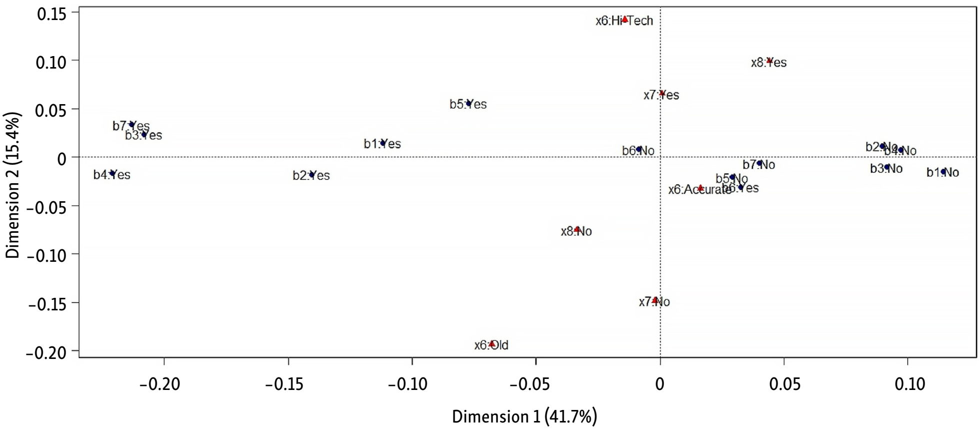

Figure 5. Technological advancement of products (variables X_6 to X_8) and barriers to industrial digitalization (source: authors' computation based on R results)

Table 3. The results of multivariate correspondence analysis for technological advancement of products (variables X_6 to X_8) and barriers to industrial digitalization (source: authors' computation with R software)

Categories of variables and barriers	Coordinates		Quality of category mapping by dimension			Contribution of categories to the dimension formation	
	axis 1	axis 2	(1) + (2) qlt	(1) qlt1	(2) qlt2	ctr1	ctr2
x6: Accurate	0.016	–0.032	0.264	0.053	0.210	0.002	0.023
x6: Hi-Tech	–0.014	0.142	0.446	0.004	0.442	0.001	0.188
x6: Old	–0.068	–0.193	0.575	0.063	0.512	0.006	0.121
x7: No	–0.002	–0.148	0.626	0.000	0.626	0.000	0.230
x7: Yes	0.001	0.065	0.626	0.000	0.626	0.000	0.101
x8: No	–0.034	–0.075	0.646	0.107	0.538	0.008	0.110
x8: Yes	0.044	0.099	0.646	0.107	0.538	0.011	0.144
b1: No	0.114	–0.015	0.717	0.705	0.012	0.082	0.004
b1: Yes	–0.112	0.015	0.717	0.705	0.012	0.080	0.004
b2: No	0.090	0.011	0.578	0.569	0.009	0.062	0.003
b2: Yes	–0.140	–0.018	0.578	0.569	0.009	0.097	0.004
b3: No	0.092	–0.010	0.645	0.637	0.008	0.074	0.003
b3: Yes	–0.208	0.024	0.645	0.637	0.008	0.168	0.006
b4: No	0.097	0.007	0.707	0.703	0.004	0.083	0.001
b4: Yes	–0.221	–0.017	0.707	0.703	0.004	0.188	0.003
b5: No	0.029	–0.021	0.234	0.154	0.080	0.008	0.011
b5: Yes	–0.077	0.056	0.234	0.154	0.080	0.021	0.029
b6: No	–0.009	0.008	0.109	0.058	0.052	0.001	0.002
b6: Yes	0.032	–0.031	0.109	0.058	0.052	0.003	0.007
b7: No	0.040	–0.006	0.495	0.483	0.012	0.017	0.001
b7: Yes	–0.213	0.034	0.495	0.483	0.012	0.091	0.006
Sum	X	X	X	X	X	1.000	1.000

Notes: qlt – the quality of representation; glt1, qlt2 – the quality of category mapping by the first or second dimension (squared correlations), respectively; ctr1, ctr2 – the contribution of categories to the formation of the first or second dimension, respectively.

Variables X_9 to X_{11} describing how a company deals with digitalization, and all the considered barriers represent the final subset to be analysed. The results of correspondence analysis are shown in Figure 6 and Table 4.

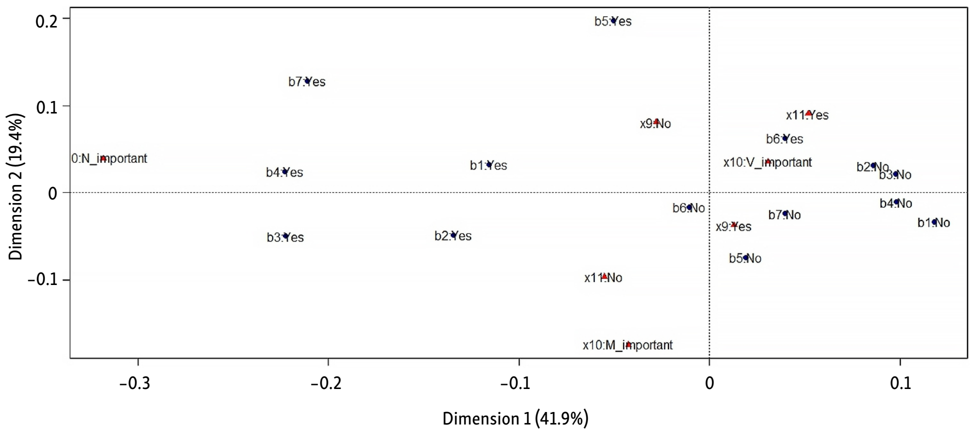

Figure 6. The approach to digital transformation (variables X_9 to X_{11}) and barriers to industrial digitalization (source: authors' computation based on R results)

Table 4. The results of multivariate correspondence analysis for approach to digital transformation (variables X_9 to X_{11}) and barriers to industrial digitalization (source: authors' computation with R software)

Categories of variables and barriers	Coordinates		Quality of category mapping by dimension			Contribution of categories to the dimension formation	
	axis 1	axis 2	(1) + (2) qlt	(1) qlt1	(2) qlt2	ctr1	ctr2
x9: No	–0.028	0.081	0.351	0.037	0.314	0.003	0.051
x9: Yes	0.013	–0.037	0.351	0.037	0.314	0.001	0.023
x10: M_important	–0.043	–0.175	0.553	0.031	0.522	0.003	0.126
x10: N_important	–0.318	0.039	0.386	0.380	0.006	0.060	0.002
x10: V_important	0.031	0.035	0.464	0.200	0.263	0.008	0.024
x11: No	–0.055	–0.097	0.511	0.125	0.386	0.017	0.111
x11: Yes	0.052	0.091	0.511	0.125	0.386	0.016	0.104
b1: No	0.118	–0.033	0.689	0.638	0.051	0.078	0.013
b1: Yes	–0.116	0.033	0.689	0.638	0.051	0.077	0.013
b2: No	0.086	0.031	0.655	0.580	0.075	0.051	0.014
b2: Yes	–0.135	–0.048	0.655	0.580	0.075	0.080	0.022
b3: No	0.098	0.022	0.701	0.667	0.033	0.075	0.008
b3: Yes	–0.222	–0.050	0.701	0.667	0.033	0.171	0.019
b4: No	0.098	–0.011	0.787	0.778	0.009	0.076	0.002
b4: Yes	–0.223	0.024	0.787	0.778	0.009	0.172	0.004
b5: No	0.019	–0.074	0.654	0.040	0.614	0.003	0.099
b5: Yes	–0.051	0.198	0.654	0.040	0.614	0.008	0.262
b6: No	–0.011	–0.017	0.273	0.078	0.195	0.001	0.005

End of Table 4

Categories of variables and barriers	Coordinates		Quality of category mapping by dimension			Contribution of categories to the dimension formation	
	axis 1	axis 2	(1) + (2) qlt	(1) qlt1	(2) qlt2	ctr1	ctr2
b6: Yes	0.040	0.063	0.273	0.078	0.195	0.004	0.020
b7: No	0.040	–0.024	0.601	0.438	0.163	0.015	0.012
b7: Yes	–0.211	0.129	0.601	0.438	0.163	0.080	0.064
Sum	X	X	X	X	X	1.000	1.000

Notes: qlt – the quality of representation; glt1, qlt2 – the quality of category mapping by the first or second dimension (squared correlations), respectively; ctr1, ctr2 – the contribution of categories to the formation of the first or second dimension, respectively.

The first dimension allows for 32.1% of total inertia. The second one for 12.0% of total inertia.

5. Discussion

Our research findings reveal that foreign high and medium high tech manufacturing enterprises operating in Poland view excessive implementation costs as the primary challenge to their digital transformation, with 51% of the respondents identifying this issue. Additionally, 39% of the companies listed uncertain market conditions as a significant obstacle, while 31% pointed to a lack of their own financial resources as a major barrier. It is generally believed that the high cost of adopting digitalisation remain a major problem for small organizations (European Investment Bank, 2023, p. 31), however, the results of the study show that it is also relevant to large manufacturing companies (82% total). Our findings present the subjective perspective of the surveyed enterprises, but they are in line with the market practice. Many businesses claim that they manage too scarce budgets to properly embark on their journey to digital transformation. Companies are already spending as much as 90% of their IT funds on the current systems, which means they lack resources to invest in more innovative and advanced digital solutions. Organizations that spend most of their IT resources to simply maintain what they already have, find it harder to become digitally advanced. Financial factors are among the most recurrent barriers throughout the source literature. High cost of system improvements is the most frequently cited barrier at an enterprise level, along with the investment and digital tools costs. Lack of funding is also often mentioned as a barrier, both at internal and external levels (Lammers et al., 2019, p. 3).

The research, which used multivariate correspondence analysis and considered the interpretative potential of the perceptual map, projected the studied variables into two dimensions. The first axis best highlights the main differences between the categories of barriers to digitalization and other variables at each stage of the research process. The second axis provides additional insights into the relationships between variables not captured by the first axis. When examining the relationship between the general characteristics of foreign enterprises operating in Poland, technological advancement of products, their approach to digital transformation, and the barriers they face, efforts were made to assign meaningful interpretations to the two-dimensional axes. This approach facilitated understanding and evaluating the occurring connections between variables and barriers to digital transformation. Each point on the perceptual map represents the average position of a variable or a barrier in the two-dimensional space.

By using two dimensions, 44.1% of the total variance in analysing the relationships between the categories of barriers to digital transformation (B_1–B_7) and the general characteristics of the analysed enterprises (X_1–X_5), was captured. For the relationship between barriers and variables describing product technological advancement (X_6–X_8) the model explained 57.1%, whereas 61.3% of the variance was accounted for in the relationship between barriers to digitalization and the approach of enterprises to digital transformation (X_9–X_{11}). This indicates that the two-dimensional space most effectively represents the structure of relationships between barriers and attitudes to digital transformation, while the weakest representation is found in the relationship between barriers and the general characteristics of enterprises.

Analysis of the perceptual map in Figure 4 and the data in Table 2 reveals insights into how the general characteristics of the studied enterprises influence their perception of barriers to digital transformation. The first axis accounts for 32.1% of the total variance, providing a reasonable representation of the identified relationships. This dimension reflects the degree of difficulty in the implementation of digital transformation. Companies with negative coordinate values on this axis tend to face significant challenges (reported barriers), while those with positive coordinate values generally encounter fewer difficulties (no reported barriers). The highest values of mapping quality indicators (correlation) by the first dimension (qlt1) allow identifying the categories whose position on the perceptual map accurately reflects their relationship with the degree of difficulty in the implementation of digitalization strategies. Focusing on the categories presenting the highest values of both indicators for the first dimension enables identifying the ones both well represented on the perceptual map and having a significant impact on defining the degree of difficulty in the implementation of digitalization strategies.

Having considered the substantive meaning of dimension one, the values of coordinates, the quality of the first-dimension mapping and the contribution to its formation, it can be adopted that the key barriers to digital transformation which differentiate enterprises the most in terms of the analysed characteristics are as follows:

a) limited availability of local partners (b7: Yes) – coordinate –0.287, qlt1 = 0.573, ctr1 = 0.086;

b) limited access to investment incentives (b4: Yes) – coordinate –0.206, qlt1 = 0.581, ctr1 = 0.086;

c) uncertain market conditions (b2: Yes) – coordinate –0.152, qlt1 = 0.487, ctr1 = 0.060;

d) lack of qualified workforce (b5: Yes) – coordinate –0.178, qlt1 = 0.452, ctr1 = 0.057.

Referring to the results of the multivariate correspondence analysis in terms of the experienced degree of difficulty in the implementation of digitalization, it can be observed that most foreign enterprises operating in Poland for 5 to 10 years (x5: from 5 to 10y) face the greatest difficulties in the implementation of digitalization (coordinate –0.314; qlt1 = 0.438; ctr1 = 0.083) and identify limited access to local partners as the most severe barrier to digital transformation (coordinate –0.287; qlt1 = 0.573; ctr1 = 0.086).

In turn, the majority of foreign companies representing the machinery manufacturing sector constitute a specific category and do not perceive such barriers. This category is characterized by a relatively high mapping quality and contribution to the first dimension (coordinate 0.448; qlt1 = 0.641; ctr1 = 0.098). It is worth noting that in most cases these are simultaneously the enterprises not planning further development in Poland (coordinate 0.384; qlt1 = 0.495; ctr1 = 0.113) and concerned about the relocation to another country (coordinate 0.329; qlt1 = 0.402; ctr1 = 0.060) – extreme positions on the perceptual map on the positive side of the first axis. On this basis, it can be concluded that the consequence of no interest shown by foreign companies to operate in Poland is also shown by the lack of commitment to further company development, including the implementation of digital transformation. As a result, the management of such enterprises may be unaware of the difficulties associated with digitalization, as they do not plan to implement it in Poland.

The second dimension is not very meaningful in identifying the structure of relationships between the general enterprise characteristics and barriers to digital transformation, as it explains only 12% of the data variation. The second dimension has been assigned the following term: *enterprise position in the supply chain*, due to axis 2 coordinate values, relatively high quality of the mapping and significant contribution of the following enterprise categories to its formation:

a) TIER 3 enterprises as a sub-supplier to another sub-supplier (x2: TIER 3) – coordinate –0.352, qlt2 = 0.31, ctr2 = 0.092;

b) OEM enterprises, manufacturers of finished products (x2: OEM) – coordinate 0.117, qlt2 = 0.358, ctr2 = 0.089.

Higher coordinate values indicate higher position in the supply chain, whereas negative values point to the companies at a lower end of the supply chain. The categories characterized by the highest values of mapping quality indicators (correlation) by the second dimension (qlt2) and the contribution to the creation of the second dimension (ctr2) are well represented and essential to determining the enterprise position in the supply chain.

The majority of foreign companies representing chemical and pharmaceutical industries (co-ordinate 0.223; qlt2 = 0.497; ctr2 = 0.102) and the so-called 'other industries' (coordinate 0.171; qlt2 = 0.127; ctr2 = 0.044) take higher positions in the supply chain.

The position of points on the perceptual map (cf. Figure 4) shows that most foreign enterprises experience fewer difficulties in the implementation of digitalization, i.e.:

1. representing automotive sector and the so-called other industries (x1: Moto, x1: Other),

2. taking TIER 1 and TIER 2 positions in the supply chain (x2: TIER 1, x2: TIER 2),

3. operating in Poland for over 10 years (x3: more than 10y).

The machinery manufacturing enterprises concerned about relocation and not planning further development in Poland constitute a group of foreign companies clearly different from others, they identify the difficulties of digital transformation to a lesser extent, and their position on the perceptual map indicates specificity and differentiation. Machinery manufacturing enterprises play an intermediate role in the production and value chain. They usually operate in the middle segment of the industrial value chains. Thus, they are more exposed to price competition and cost-efficiency pressures than innovation-driven industries. Usually, products of machinery manufacturing enterprises are not strongly differentiated, making them more commoditized and replaceable. On the other hand, such enterprises tend to have lower levels of R&D intensity, as well as, slower digitalization transformation. Many of machinery producers in Poland are subsidiaries of larger foreign corporations. In such a case, global evaluation of locations and global optimization may not view Poland as a strategic hub, but as a cost-effective location. This makes long-term investments less likely (see for example Śledziewska & Włoch, 2024; Sudolska & Łapińska, 2020; Snieška et al., 2020; Turovets & Vishnevskiy, 2019). Besides other papers report similar findings to those observed in Poland – they also indicate that machinery manufacturing enterprises often face challenges related to digitalization and innovation, which can influence their decisions regarding relocation and development (see for example Arnarson et al., 2023; Zangiacomi et al., 2019; Meng & Gong, 2024). All these papers collectively suggest that machinery manufacturing enterprises across various countries encounter comparable challenges related to digitalization and innovation. The degree to which these challenges influence decisions about relocation and development varies based on factors such as organizational readiness, technological infrastructure, and market conditions.

Greater difficulties in the implementation of digitalization were revealed by the vast majority of foreign companies in the high and medium high-tech sector representing:

1. aerospace, electronics and electrical engineering, and also chemicals and pharmaceuticals (x1: Aero, x1: Elec, x1: Ch&Ph),
2. OEM position in the supply chain (x2: OEM),
3. operating in Poland for 5 to 10 and less than 5 years (x3: from 5 to 10y, x3: less than 5),
4. uncertain or unsure of relocation (x4: Maybe, x4: No),
5. maybe planning and planning further development in Poland (x5: Maybe, x5: Yes).

Most foreign companies operating in the Polish market for 5 to 10 years of experience all barriers to digital transformation identified as the key ones. The majority of companies representing aerospace as well as electronics and electrical engineering sectors identify similar barriers, including primarily no skilled workforce (b5: Yes), high implementation costs (b1: Yes), uncertain market conditions (b2: Yes) and lack of information about the actual benefits (b6: Yes).

The majority of foreign companies not concerned about relocation (X_4: No) and planning further development in Poland (X_5: Yes) associate the difficulties in the implementation of digitalization predominantly with high implementation costs (b1: Yes) and lack of information about the actual benefits (b6: Yes). No information about the actual benefits (b6: Yes) also bothers the majority of high and medium high-tech companies occupying the OEM position in the supply chain (X_2: OEM), as well as those expressing uncertainty about both relocating to another country (X_4: Maybe) and planning further development in Poland (X_5: Maybe).

Foreign enterprises operating in the chemical and pharmaceutical industry (x1: Ch&Ph) are diverse and specific in terms of the second dimension, and relate the difficulties in the implementation of digitalization mainly to the lack of information about the actual benefits (b6: Yes). The majority of high and medium high-tech enterprises functioning in Poland for the shortest period of time (x3: less than 5) struggle primarily with the lack of their own financial resources allocated to digital transformation (b3: Yes).

Foreign high and medium high-tech enterprises least affected by the implementation of digitalization mostly include the companies representing automotive sector (x1: Moto), as well as those from the so-called other sectors (x1: Other), the enterprises taking the TIER1 and TIER2 positions in the supply chain and operating in the Polish market for more than 10 years. Most automotive companies at the TIER1 position in the supply chain do not identify the lack of information about the actual benefits resulting from digitalization. Most enterprises taking the TIER1 position and operating in the Polish market for more than 10 years are not concerned about the indicated barriers to digital transformation. The TIER3 companies belong to a specific category regarding the analysed enterprises and variables, their positioning on the perceptual map indicates a particular difference and differentiation comparing to other categories of variables – both the characteristics of enterprises and the degree of perceived difficulties in the implementation of digitalization. This situation results from the fact that the TIER 1 and TIER 2 suppliers can depend on the level of digitalization of the OEM type of enterprises which target the end user. High tech industries require their suppliers to have stringent quality certifications and consistency in information flow and logistics management systems. This makes it imperative for the TIER 1 and TIER 2 enterprises to meet the requirements of end-goods manufacturers, also in terms of digital transformation. The benefits of this process are clear for them – without digitalization, they will not be able to maintain their market position.

Based on Figure 5 and the data in Table 3, an analysis of the relationship between the degree of product advancement and the difficulties in implementing digital transformation experienced by foreign high and medium high-tech enterprises operating in Poland, can be conducted.

Adopting two dimensions in the multivariate correspondence analysis allowed, in this case, to explain 57.1% of the data variability, which means that they represent most of the information contained in the analysed variables. The first axis explains the largest part of the total data variability (41.7%). The higher the values taken by the coordinates of the categories representing the presence of barriers, the lower the degree to which foreign companies experience difficulties in their implementation. Therefore, axis one, as in the previous stage of the analysis, can be defined as: *the degree of difficulty in implementing digital transformation*. The interpretation of mapping quality indicators and contribution to dimension 1 is analogous to the analysis of relationships occurring between general characteristics of the enterprise and the identification of barriers to digitalization.

The following difficulties experienced in the implementation of digitalization can be considered the key ones, i.e., those most differentiating enterprises characterized by a different degree of technological advancement of the manufactured products (due to the category positioning on the perceptual map – negative values of coordinates, relatively high quality of mapping by the first dimension and a significant contribution to the dimension creation):

a) limited access to investment incentives (b4: Yes) – coordinate –0.221, qlt1 = 0.703, ctr1 = 0.188;

b) limited availability of local partners (b7: Yes) – coordinate –0.213, qlt1 = 0.483, ctr1 = 0.091;

c) lack of own financial resources (b3: Yes) – coordinate –0.208, qlt1 = 0.637, ctr1 = 0.168.

When analysing the categories which describe variables related to technological advancement of the product, it is noticeable that the enterprises producing a technologically outdated product (x6: Old) and without a 3-year plan for implementing innovative products (x8: No) are most affected by barriers to digitalization (coordinate values, respectively: –0.068 and –0.02). However, the enterprises with a 3-year plan for implementing smart products (x8: Yes) experience far fewer difficulties in this area (coordinate 0.044).

Regarding the second dimension, it was found that the following categories referring to product technological advancement show positive values of coordinates and relatively high values of mapping quality indicators as well as the contribution to the creation of the second dimension:

a) high tech product (x6: High Tech) – coordinate 0.142, qlt2 = 0.442, ctr2 = 0.188;
b) introduction of a new/improved product in the last 3 years (x7: Yes) – coordinate 0.065, qlt2 = 0.626, ctr2 = 0.101;
c) 3-year plan for the implementation of a technologically advanced product (x8: Yes) – coordinate 0.099, qlt2 = 0.538, ctr2 = 0.144.

In turn, negative values of the second axis coordinates were recorded for the categories defining foreign enterprises manufacturing obsolete products (x6: old) and also the companies which did not launch either a new or a technologically improved product in the last 3 years (x7: No) – coordinates of the above variable categories, respectively: –0.193 and –0.148. To sum up, the second dimension can be defined as the *level of technological innovation of products*. The companies whose manufactured or planned products are more technologically advanced will take higher values in the second dimension.

The following conclusions can be drawn from the position of points on the perceptual map (Figure 5) in the context of dimensions:

1. the categories of variables placed in the upper right part of the perceptual map indicate that the majority of foreign companies producing high tech products (x6: High-tech), which have launched an innovative product in recent years (x7: Yes) and plan to launch a sophisticated product in the next 3 years (x8: Yes) are well prepared for the implementation of digital transformation and are experiencing the respective difficulties to a lesser extent;
2. the categories of variables placed in the lower left part of the perceptual map indicate that the majority of the surveyed companies producing obsolete products (x6:old), which have not launched a sophisticated product in recent years (x7: No) and do not plan to do so in the next 3 years (x8: No) are poorly prepared to implement digitalization, face greater difficulties in doing so and are characterized by low product innovation.

The analysis of the proximity of points on the perceptual map shows that the majority of foreign companies which do not experience excessive costs of implementing innovations (b1: No) are also not concerned about uncertain market conditions (b2: No), lack of own financial resources (b3: No) and limited access to investment incentives (b4: No). On the other hand, most foreign companies identifying the lack of their own financial resources (b3: Yes) as a significant barrier to digital transformation also recognize the difficulties associated with limited availability of local partners (b7: Yes) and limited access to investment incentives (b4: Yes). In turn, the majority of enterprises manufacturing products technologically adapted to market requirements (x6: Accurate) identify the lack of information about current benefits (b6: Yes) as a barrier to digital transformation, and are not concerned about the lack of skilled workforce (b5: No) or limited availability of local partners (b7: No).

Using the perceptual map shown in Figure 6 and the results of calculations presented in Table 4 allows analysing relationships between the attitude of high and medium high tech foreign companies towards digital transformation and their perception of its barriers. As in the previous stages of the analysis, a two-dimensional variable projection space was adopted, which allowed explaining 61.3% of total inertia. This indicates a fairly good data representation in this space. The first axis explaining 41.9% of data variation can be described as the *degree of difficulty in implementing digital transformation*. The left side of the axis presents companies experiencing and the right side not experiencing the examined barriers. The key barriers that most differentiate companies characterized by a different approach to digital transformation, having considered the coordinates of the first axis, high mapping quality by the first dimension and the significant participation in the creation of the first dimension, can be identified as follows:

a) limited access to investment incentives (b4: Yes) – coordinate –0.223, qlt1 = 0.778, ctr1 = 0.172.

b) lack of own financial resources (b3: Yes) – coordinate –0.222, qlt1 = 0.667, ctr1 = 0.171;

c) limited availability of local partners (b7: Yes) – coordinate –0.211, qlt1 = 0.438, ctr1 = 0.080;

The category associated with the greatest difficulties in the implementation of digitalization, characterized by high mapping quality and contribution to the first dimension covers foreign companies approaching digitalization as not important for them (x10: N_important, coordinate –0.318, qlt1 = 0.380, ctr1 = 0.060). These enterprises face the greatest difficulties in the implementation of digitalization, which mainly include the aforementioned key barriers to digital transformation.

The following categories showed negative values of coordinates the second dimension of data projection, and also a relatively high-quality representation of the second dimension and a significant contribution to its creation:

a) the importance of digital transformation for the company (x10:M_important) – coordinate –0.175, qlt2 = 0.522, ctr2 = 0.126);

b) lack of digitalization strategy (x11: No) – coordinate –0.097, qlt2 = 0.386, ctr2 = 0.111.

On the other hand, having a digitalization strategy (x11: Yes) is characterized by a positive coordinate value (0.091) and high values of other characteristics (qlt2 = 0.386, ctr2 = 0.104). The implementation or non-implementation of digitalization in the last 3 years of the enterprise operation (X9: Yes and X9: No, respectively) has not been the key factor contributing to the creation of the second dimension (qlt2 = 0.023 and qlt2 = 0.051, respectively).

The second projection dimension was assigned the following term – *strategic digital readiness of an enterprise*. Foreign companies, better prepared to implement digital transformation are characterized by higher values in the second dimension.

The following conclusions can be drawn from the position of points on the perceptual map (Figure 6) in the context of dimensions:

1. the categories of variables placed in the upper right part of the perceptual map indicate that the majority of foreign companies attributing very high importance to digital transformation (x10: V_important), having a global digitalization strategy (x11:

Yes), which have implemented digitalization in the last 3 years (x9: Yes) are strategically ready to implement digital transformation and are not experiencing significant difficulties in this respect;

2. the categories of variables located in the bottom left part of the perceptual map indicate that the majority of surveyed companies for which digitalization is moderately important (x10: M_important) and do not have a global digitalization strategy (x11: No) are not strategically prepared to implement digital transformation and are experiencing numerous barriers to digital transformation.

The proximity of the points on the perceptual map shows that the majority of foreign companies attributing high importance to digital transformation (x10: V_important) have implemented it in the last 3 years and also have a global digitalization strategy (x11: Yes). Furthermore, the majority of these companies do not experience key barriers to digital transformation (b1: No, b2: No, b3: No, b4: No). Instead, they perceive difficulties related to the lack of information about the actual benefits of digitalization (b6: Yes) and the lack of skilled workforce (b5: Yes). In turn, the majority of foreign companies for which digitalization is not very important (x10: No) also do not have a global digitalization strategy (x11: No) and identify barriers related to the implementation of digitalization to a much greater extent. The majority of companies that have implemented digitalization in the last 3 years (x9: Yes) are not concerned about the absence of information about its actual benefits (b6: No), the lack of qualified workforce (b5: No), or limited availability of local partners (b7: No).

The relationships occurring between the degree of difficulty in the implementation of the digitalization strategy identified by an enterprise and the strategic readiness of an enterprise to digitize remain most relevant to the analysis results, as these dimensions showed the highest contribution to explaining the total inertia, i.e. the dispersion of the analysed categories in the actual multidimensional space, compared to the previously analysed relationships (between the degree of difficulty in the implementation of the digitalization strategy and the general statistics of the enterprise and the technological advancement of products).

The location of digitalization barriers against each other on the perceptual maps is also worth noting, as it reflects the degree of their co-occurrence in the surveyed enterprises. In turn, assessing the position of digitalization barriers regarding the categories of analysed variables allows assessing which variables influence the perception of a particular barrier. The barriers located on the perceptual map close to the origin of coordinates are more universal and are present in most companies regardless of the variables describing them, hence they are less important in identifying the studied relationships.

Barrier B_1 (excessive implementation costs) is often close to barriers B_5 (lack of skilled workforce) and B_2 (uncertain market conditions). These barriers are related to both the labour market (B_5, B_1) and the economic and political situation in Poland (B_1, B_2, partly B_5 along with the absence of support for appropriate education forms relevant to market needs).

Barrier B_1 is important and most often identified by the companies operating in aerospace (X1: Aero) and electronics and also electrical engineering (X1: Elec), more broadly for most companies planning to expand in Poland (X5: Yes). It is also important for high-tech companies (X6: Hi-Tech), and for the companies where digitalization is very important (X10: V). It is also crucial for the majority of companies where digitalization has not been implemented in the last 3 years (X9: No) and the global digitalization strategy has not been developed (X11_No).

Barrier B_3 (lack of own financial resources) is particularly relevant for most companies operating in Poland for a short time (less than 5 years in business- X3: less than 5y) and are planning further development in Poland (X5: Yes). Regarding the aspect of technological advancement of company products, this barrier is closely related to barriers B_7 (limited availability of local partners) and B_4 (limited access to investment incentives). Having considered the approach to digital transformation, including barriers B_4 (limited access to investment incentives) and B_7 (limited availability of local partners) is important to the majority of companies declaring that digitalization is not important to them (X10: N_important). These barriers seem to have a stronger impact on the companies in their early stages of development or the ones perceiving digitalization less important as funding is required in other aspects of the business (perhaps insufficient funds for digitalization), the company may not yet fully recognize the local or national labour market and the existing models and methods of support available in the market (this may result from "contentment" with the current position in the market or the company passivity towards digitalization).

Barrier B6 – lack of information on actual benefits refers to most of the original equipment manufacturers (X2: OEM), the companies characterized by a high degree of uncertainty about their future (they are unsure about relocation to another country (X_4: Maybe), they are also not certain about further development or the lack of it in Poland (X_5: Maybe)). The perception of this barrier does not significantly differentiate the surveyed enterprises considering the technological advancement of products and the approach to digital transformation.

It is important to note certain potential limitations of the obtained results and interpretation. Three main types of limitations can be identified, which include as follows:

1) geographical concentration of the sample – the research focused on large enterprises operating in Poland, which may limit the transferability of results to other markets or regions;
2) lack of a dynamic perspective – the analysis is based on a one-off study, not allowing the observation of changes over time;
3) methodological limitations – multivariate correspondence analysis simplifies complex relationships between variables, assumes their linearity and homogeneity of variance of all categories, which may not always reflect the reality and result in losing detailed information.

The limited number of respondents operating in specific industries resulted from the geographical limitation of the study, thus, it is difficult to draw overarching conclusions about them. Further research is required to provide more in-depth and grounded evidence for industry-specific features associated with barriers to enterprise digital transformation. To overcome the limitations connected with the research covering the impact of various factors on the digital transformation of high and medium high-tech enterprises, in the future, it is worth expanding the research sample by increasing the number of companies participating in the survey to include foreign companies operating in different geographical regions and using a dynamic approach that considers changes over time. This will also allow spatial-temporal comparative studies to be carried out. In addition, it is also worth using other methods of multivariate data analysis, including, e.g., logistic models and cluster analysis techniques, which enable obtaining more detailed results.

Although the data were collected in 2020, at the onset of the COVID-19 pandemic, it is important to recognize that the structural barriers identified – and their interrelationships – remain pertinent despite the temporal gap. Many of the barriers examined (e.g., those concerning investment incentives, the availability of local partners, and strategic readiness) are likely to constitute enduring challenges beyond the immediate context of the pandemic. Nevertheless, longitudinal and spatial-temporal comparative studies would provide a more nuanced understanding of their evolving significance for organizations undergoing digital transformation.

Although global enterprises are well equipped in terms of digital tools, there are greater difficulties and obstacles to implementing further digitalization and intelligent processes in the supply chain due to the lack of industry-specific guidelines, strategic orientation and relevant knowledge (Wang et al., 2022, p. 364). Digital transformation involves not only deploying technologies within a company but also integrating with large-scale communication and information infrastructures while adhering to laws and regulations (Adler-Milstein, 2021).

Working with the automotive suppliers, Burkacky et al. (2018) identified six core areas enabling successful digital transformation of large manufacturers. They are as follows: developing a distinctive digital strategy that considers the myriad new ways value can be created with digital technology, establishing a digital centre of competence within the existing organizational structure, launching digital pilot projects and applying test-an-learn approach, attracting cutting-edge talent and capabilities, leveraging and creating supportive business ecosystem, as well as implementing the culture of exchange and interaction (Burkacky et al., 2018).

In 2023, Senna et al. analysed the digital policies of 27 European Union countries, highlighting barriers to digital transformation. Their findings for Poland emphasized the need for support in the areas such as investment in digital transformation (e.g., through tax relief for business robotization), education to demonstrate the benefits of digitalization, improving digital infrastructure and cybersecurity, and enacting legislative changes to promote the digital economy (Senna et al., 2023, p. 8). Empirical research on international location strategies shows that low digital maturity of a foreign enterprise in the host economy encourages its disinvestment in favour of the home country or other regions (Barbieri et al., 2022, p. 2; Dachs et al., 2019, pp. 8–10; Kinkel et al., 2017, p. 27; Kinkel, 2020, p. 208), while high digital maturity promotes reinvestments, even during such challenging periods as COVID-19 pandemic (Pokorska, 2023, p. 227).

Moreover, further research in the field could help address the "Productivity Paradox", proposed by Robert Solow, who observed that the computer age was noticeable everywhere but in the productivity statistics (Solow, 1987). Currently, it is referred to as the "Digitalization Paradox" which means that investment in digital transformation does not necessarily reflect the firm performance nor secure the corresponding revenue increase (Guo et al., 2023, pp. 2–3).

In particular, our findings align with prior research indicating that companies operating in environments with lower levels of digital maturity and underdeveloped institutional support structures face unique barriers that are not fully captured by the resource-based view (Henriette et al., 2015; Hinings et al., 2018).

6. Conclusions

Although our research examining the relationships between barriers to digital transformation and specific enterprise characteristics was conducted in 2020, at the beginning of the COVID-19 pandemic, a time when both the public and private sectors were experiencing a digital shift, the results of the survey, along with the multivariate correspondence analysis, offer valuable insights. These findings are useful not only for policymakers but also for enterprises themselves. Overcoming barriers to digital transformation requires awareness of its critical role in driving enterprise development, enhancing global competitiveness, and boosting innovation and operational efficiency. Digitalization is a long-term process that demands careful planning and execution. Key factors which support this process include organizing regular activities to develop and implement detailed plans for launching innovative and improved products, as well as creating and executing global digitalization strategies.

Among the foreign high and medium high-tech manufacturing enterprises operating in Poland, 51% identified excessive implementation costs as the primary challenge related to digital transformation, while 39% pointed to uncertain market conditions and 31% to the lack of financial resources. The multivariate correspondence analysis revealed that limited access to investment incentives (B4) and limited availability of local partners (B7) were the main barriers that distinctly differentiated foreign high and medium high-tech enterprises in Poland across all examined factors, including the structure of relationships between barriers and their general characteristics, product technological advancement, and approach to digital transformation. Further analysis of the relationships between barriers and product technological advancement, as well as approaches to digital transformation, showed that the lack of financial resources (B3) and uncertain market conditions (B2) were also the significant factors distinguishing the enterprises in question. Barriers identified by the respondents reflect their immediate concerns, such as excessive implementation costs or uncertain market conditions. However, the barriers highlighted through perceptual map analysis (MCA) are the ones most significantly differentiating enterprises based on their characteristics, technological advancement, and approach to digital transformation. By combining these two perspectives – subjective perceptions of enterprises and objective analyses of differentiation – it becomes clearer which barriers require urgent action and which demand long-term structural interventions. The most significant challenges related to digital transformation were faced by foreign enterprises which:

- Have been operating in Poland for no more than 10 years, are unconcerned about relocation to a different market, and plan further development in Poland.
- Serve as OEMs in the supply chain, for whom integrating both suppliers and customers within their digital systems can be costly and technologically complex.
- Manufacture outdated products, have not launched a new or improved product in the past three years, and do not plan to do so in the next three years.
- View digitalization as moderately important and lack global digitalization strategy.

Conversely, certain qualities help enterprises overcome digitalization challenges. These include recognizing the critical role of digitalization for the company's growth, manufacturing innovative products, having prior experience with digital transformation, and planning further product innovations while implementing a global digitalization strategy. Our research highlights the critical relationship between a company's perceived difficulty in implementing the digital strategy and its strategic readiness for digital transformation. Digital readiness is reflected in an organization's awareness of the importance of digital transformation for its continued growth, the presence of a comprehensive globalization strategy, and experience in its execution. Companies with higher digital readiness are better equipped to overcome any barriers. Recognizing the impact of digital transformation on growth and competitiveness increases the company's willingness to invest in new technologies. A well-defined digital strategy enables structured planning while mitigating the risk of failure. Additionally, experience in implementing digital initiatives enhances operational efficiency. Therefore, digital transformation requires prior preparation, followed by an assessment of the company's readiness for implementation.

Other general characteristics of foreign enterprises that enable digital transformation include operating in the Polish market for 10 years or more and holding TIER 1 or TIER 2 positions in the supply chain. Companies that have operated more than 10 years in Poland, benefit from long-term experiences and well-established business ecosystems in their host economy. Additionally, the digital transformation of TIER 1 and TIER 2 suppliers is usually motivated by the needs and expectations of their corporate customers (OEMs), which makes it easier for them to undertake digital investments and guarantee payback. Also, companies in the automotive and, so called, "other" industries encounter digital transformation barriers to a much lesser extent. This difference is likely due to the automotive industry's high level of production automation, which naturally integrates into the digital environment by enabling machine communication and data analysis throughout the product life cycle.

In turn, most enterprises that struggle in digital transformation can be found in the aerospace, electronics, electrical engineering, and also chemical and pharmaceutical industries. Due to the limited number of respondents operating in these industries it is difficult to draw overarching conclusions, but clearly, the entities with stringent regulatory and technological demands (e.g., pharmaceuticals) or lower production volumes and less repeatability (e.g., aerospace) encounter greater challenges in adopting digital technologies. Machinery manufacturing companies seem to be unique as they do not report major difficulties in implementing digital transformation. However, they express great concerns about the risk of relocation from Poland to other host economies and have no plans to further develop their operations in the local market. Addressing this issue may require targeted governmental support strategies to encourage corporate investment and expansion in the industry in question.

In fact, the relationship between barriers to digital transformation and specific enterprise characteristics offer practical implications for business managers, policymakers, and government bodies. Although global enterprises are well equipped with digital tools, they face significant challenges in advancing supply chain digitalization and implementing intelligent processes due to a lack of industry-specific guidelines, strategic direction, and relevant expertise.

The most frequently reported barriers in our study include excessive digitalization costs, uncertain market conditions, and lack of internal resources, while the factors differentiating foreign enterprises the most are connected to the scarcity of investment incentives and capable local partners within the local business ecosystem. Digital transformation entails not only the internal deployment of technologies within a company but also their integration with large-scale communication and information infrastructures, all while ensuring compliance with relevant laws and regulations.

Six core areas for automotive suppliers that are as follows: developing a distinctive digital strategy that considers the myriad new ways value can be created with digital technology, establishing a digital centre of competence within the existing organizational structure, launching digital pilot projects and applying test-an-learn approach, attracting cutting-edge talent and capabilities, leveraging and creating supportive business ecosystem, as well as implementing the culture of exchange and interaction.

Therefore, policymakers should take these digital enables under consideration when offering financial support for businesses and implementing market stabilization measures. Effective support could address not only small and medium-sized enterprises through grants, subsidies, and support programs, but also include large companies i.e., by means of offering tax reliefs to those who develop technological capabilities, as it would motivate them to invest in more advanced and value-added activities in the Polish market. Any support should apply the sectoral approach as well. For example, the successful implementation of Industry 4.0 technologies in the aerospace industry requires significant investment in infrastructure, training, and education, as well as a fundamental shift in the way the industry thinks about maintenance, operations, and supply chain management (Bhatia et al., 2024, p. 429). On the other hand, by embracing digital technologies, the pharmaceutical industry can achieve a new level of quality, efficiency, and patient-centricity while maintaining compliance with evolving regulatory requirements. However, to successfully implement them, close collaboration between pharmaceutical companies, regulators, and industry associations is required.

Policymakers play a vital role in addressing barriers to digital transformation by introducing initiatives that help businesses navigate the challenge. Taking China as a specific example, The Ministry of Industry and Information Technology proposed that digital transformation will be preliminarily realized in key industries by 2025 (more than 2,000 smart scenarios for the application of new technologies, more than 1,000 smart workshops, and more than 100 benchmark smart factories leading the Industry 4.0 development). As a result, the income of smart manufacturing business increased from 73.467 million yuan in 2017 to 413.252 million yuan in 2020. In the European Union, national digital policies have emphasized the significance of financial support for digitalization investments, workforce upskilling and reskilling, as well as appropriate legal and regulatory framework implementation. To gauge the effectiveness of these efforts, future studies should analyse not only the occurrence of digital transformation barriers, but also their interrelations with specific business characteristics. Large multinational companies, the leaders in digital transformation can serve as benchmarks for identifying trends and challenges, because they often face similar obstacles to smaller entities.

Further and more comprehensive research findings can guide the effective targeting and selection of governmental support mechanisms for businesses undergoing digital transformation as well as strengthen the company leadership and strategy as it goes in line with the Resource-Based View managerial theory. High and medium high-tech enterprises must embrace and benefit from digital transformation, not only to remain viable but also to thrive in a rapidly evolving business landscape. In addition, the companies investing in digital transformation are more likely to adopt sustainability practices and contribute to climate protection, aligning with the principles of the circular economy (European Investment Bank, 2023, p. 36).

The results of the conducted study make a significant contribution to the development of digital transformation theory by emphasizing the importance of institutional and network-related factors in the digitalization process of large foreign enterprises operating in emerging markets. The identified barriers, such as limited access to local partners (B7) and insufficient availability of investment incentives (B4), point to critical external conditions that are insufficiently considered in classical theoretical frameworks.

However, our findings suggest that external constraints – such as the lack of access to local partnerships or systemic institutional support – may equally, or in some cases even more strongly, influence the pace and scope of digital transformation. In this context, the study provides empirical support for integrated theoretical approaches that combine the resource-based perspective (internal conditions) with institutional and network perspectives (external conditions).

Furthermore, by analyzing digitalization barriers in large foreign enterprises, this article addresses a gap in the literature, which has thus far predominantly focused on domestic firms or the SME sector. The findings highlight the importance of considering factors related to the limited integration of these firms into local economic and institutional environments. The lack of extensive local networks, restricted access to contextual information, and insufficient relationships with local stakeholders may significantly hinder the implementation of digital transformation strategies – even for organizations with substantial technological and financial resources.

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Author contributions

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APPENDIX

A. The main assumptions and limitations of the MCA

The key assumptions of MCA are:

a) MCA assumes that the dataset consists of categorical variables. It can be used for continuous data after discretization (Zhao et al., 2024),

b) Negri et al. (2024) warn that categories with very low frequencies may be underrepresented in MCA projections (homogeneity of categories),

c) Sarkissian et al. (2025) note that high dependencies (correlations) between categorical variables can lead to misleading associations in the MCA factor space,

d) MCA requires a sufficiently large dataset to produce stable results. Small sample sizes may result in unstable eigenvalues and misleading interpretations (Etz et al., 2024),

e) Chakraborty and Datta (2024) highlight that the first two or three dimensions usually explain the majority of the data variance, but minor dimensions may still carry important information,

f) Zhao et al. (2024) mention that this makes MCA suitable for non-parametric data but also means that hypothesis testing is not directly applicable,

g) MCA treats all categorical variables equally regardless of their importance, meaning that all variables contribute equally to the analysis. Fruchtman et al. (2025) argue that this assumption can be problematic in datasets where some variables have significantly more explanatory power than others,

h) MCA assumes that relationships between categories can be meaningfully represented in a low-dimensional Euclidean space, even though categorical data may not naturally fit such a representation.

In the conducted research, the aforementioned assumptions can be considered fulfilled.

The main limitations of MCA are:

a) Kalantan et al. (2025) highlight that while MCA helps visualize relationships, it does not provide direct causal interpretations or clear separation of categorical variables (interpretability challenges),

b) Ferrari et al. (2025) note that increasing the number of variables increases noise, reducing interpretability (high-dimensional data challenges),

c) Dalal et al. (2024) recommend to be cautious as MCA heavily depends on how categories are defined. If categories are unbalanced or poorly chosen, the results may be misleading (sensitivity to coding categories),

d) Sivertsen (2025) mentions that MCA's complexity increases exponentially as the number of categorical variables grows, requiring advanced computational techniques (computational intensity),

e) Zhao et al. (2024) argue that the method reliance on inertia maximization can lead to inconsistent factor loadings across different data samples (instability of eigenvalues and contributions),

f) Zhang et al. (2024) indicate that reducing multiple categories into a few dimensions sacrifices detailed insights, especially when dealing with heterogeneous datasets (loss of information),

g) Fontaine and Neys (2024) suggest that extreme cases may dominate the analysis, reducing the effectiveness of clustering and classification (lack of robustness to outliers),

h) Severeyn et al. (2024) emphasize that without inferential statistics, results from MCA should be supplemented with additional confirmatory analysis.

B. Results of chi-squared test of independence (p-values)

Table B1. P-values for general characteristics of the enterprise

	X_1	X_2	X_3	X_4	X_5
X_1	–				
X_2	0.2653	–			
X_3	0.0788	0.7391	–		
X_4	0.8378	0.6117	0.9608	–	
X_5	0.3863	0.3083	0.1694	0.2673	–

Table B2. P-values for technological advancement of products

	X_6	X_7	X_8
X_6	–		
X_7	0.0849	–	
X_8	0.2309	0.0709	–

Table B3. P-values for approach to digitalization of processes

	X_9	X_{10}	X_{11}
X_9	–		
X_{10}	0.3063	–	
X_{11}	0.5192	0.0739	–

Table B4. P-values for barriers of digitalization

	B_1	B_2	B_3	B_4	B_5	B_6	B_7
B_1	–						
B_2	0.6837	–					
B_3	0.4959	0.1099	–				
B_4	0.0607	0.1039	0.6294	–			
B_5	0.3911	0.3678	0.9748	0.3313	–		
B_6	0.9577	0.7911	0.2944	0.9541	0.4188	–	
B_7	0.8127	0.0795	0.0662	0.0745	0.2249	0.9132	–