European Research Studies Journal
Volume XXIX, Issue 2, 2026

pp. 722-754

Dynamics of Business Model Innovation in Materials Production and Processing Enterprises

Submitted 20/04/26, 1st revision 14/05/26, 2nd revision 28/05/26, accepted 30/06/26

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Abstract:

Purpose: *The purpose of this study was to assess the dynamics of changes in Business Model Innovation (BMI) in the context of factors driving these changes, selected based on a literature review. The following factors, which act as driving forces for change, were selected for the study: the level of digital innovations uptake, initiatives promoting sustainable development, and competitiveness.*
Design/Methodology/Approach: *The research method used was a diagnostic survey and the research technique was computer-assisted telephone interviews (CATI). The research was carried out on a sample of n=100 manufacturing companies in Poland.*
Findings: *The study presents the level of digital innovation uptake in enterprises and the sustainability initiatives undertaken by these enterprises. It demonstrates the existence of statistically significant correlations between the level of digital innovation adoption, sustainability and competitiveness.*
Practical Implications: *The research may serve as a reference for the manufacturing sector regarding the adoption of digital innovations and sustainable development initiatives, and their impact on competitiveness. The research findings presented may also be used to streamline industrial policy supporting the BMI.*
Originality/Value: *The research presented here is based on an original, proprietary approach to the study of BMI. Primary data from the business sector was used. The value of this research lies in demonstrating the relationships between complex variables – the level of digital innovation uptake, sustainability and competitiveness – as well as the role these variables play as driving forces behind changes in the BMI.*

Keywords: *Business model innovation, digital innovation, sustainability, production sector, competitiveness.*

JEL codes: *M11, M15, O32, Q56.*
Paper type: *Research paper.*

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1. Introduction

For businesses to operate competitively in a turbulent economic environment characterised by change, increasing competition, external and internal pressures, threats and emerging opportunities, they must adopt a new or significantly revised business model that harnesses innovation. Competitiveness and resilience, in conjunction with business sustainability in the context of digital transformation, are hallmarks of Business Model Innovation (BMI).

Owing to its significance in the modern economy, BMI is the subject of numerous studies (as indicated in the theoretical section of this paper), making the research topic addressed in this article—the dynamics of BMI change—topical and important. In particular, the research focused on enterprises' BMIs, the changes taking place within them, and the identification of the driving forces behind these changes, such as digital innovation, sustainable development practices and competitiveness.

At present, there is a lack of detailed research in Poland and across Europe on changes in the BMI of enterprises in the materials production sector; the research undertaken in this article should, at least in part, fill this gap. Given the significance of this research for Polish and EU industry, its findings may be useful for shaping industrial and regional policy, regarding the use of instruments to support enterprise competitiveness and reduce the risks associated with their implementation of innovations. This is particularly important considering the declining competitiveness of EU industry.

The purpose of this study was to assess the dynamics of changes in Business Model Innovation in the context of factors driving these changes, selected because of a literature review. The selected factors acting as drivers of change are the level of digital innovations uptake, sustainable initiatives and competitiveness. Furthermore, the aim of the study was to identify the relationships between the driving forces of change in the models under investigation.

To achieve the study's objectives, verify the research hypotheses and answer the research questions, a diagnostic survey and statistical analysis were employed – that is, both quantitative and qualitative methods. The research sample comprised 100 innovative large, medium and small enterprises operating in the sector of plastic, metal and ceramic product manufacturing; their activities fall within four sections of the PKD statistical classification: 22, 23, 24 and 25.

Demand for the sector's products is growing on both the global and domestic markets. The competitive potential of the analysed sector producing plastic, metal and ceramic products was estimated based on the number of active enterprises, their workforce and revenue generated. The number of enterprises operating in the sector in 2023 stood at over 116,000 (GUS, 2025), which was almost 10 per cent more than

five years earlier; in the Silesian Voivodeship, there were over 13,000 such enterprises in 2023 (BDL GUS, 2025). Between 2019 and 2024, sales increased by over 50 per cent, reaching PLN 527 billion (GUS, 2025), with employment standing at over 650,000 workers in 2022.

The summary figures presented demonstrate the significant and dynamic competitive potential of the materials production and processing sector; furthermore, its importance to the economy is determined by the sector's products, which are used in almost all areas of life, particularly in construction, the automotive industry, the manufacture of household appliances and the defence industry.

To achieve competitiveness and meet new customer requirements relating, for example, to sustainable development, changes are necessary in the management of materials production and processing enterprises, for which the application of various types of innovation (including digital innovations) in their business models.

This situation forms the background to the research undertaken into changes in business models. as part of the project 'Network of Regional Specialist Observatories in the Process of Entrepreneurial Discovery in the Silesian Voivodeship' (hereinafter referred to as the Project). The article is of a theoretical and empirical nature.

The theoretical section presents a synthetic and critical review of the literature on the research topic. This review is systematised, beginning with a presentation of classical approaches and concepts of business models, followed by an examination of the importance of innovation in value creation, and concluding with a presentation of various views on the Business Model Index (BMI).

The research methods employed in the empirical part of the study are outlined. This section presents an analysis of the diagnostic survey questions and a statistical analysis of the relationships between the factors driving changes (drivers) in the BMI. The study concludes with the research findings, a discussion of the achievement of the study's objectives, answers to the research questions, and the verification of the research hypotheses.

2. Literature Review

The theory and practice of business models have for many years constituted an important area of strategic management, corporate management and innovation management. A great many business model concepts have been developed (Svejenova, Planella and Vives, 2012; Demil and Lecocq, 2010; Osterwalder and Pigneur, 2010; Prahalad and Krishnan, 2010) which are reflected both in their definitions and in the configurations of their structure (Yahaya *et al.,* 2020).

This stems from the multidimensional and, at the same time, interdisciplinary nature

of this important strategic instrument, which poses methodological challenges in its study; hence the emerging calls for the creation of a common academic platform to enable better and more effective research into business models (Zott *et al.,* 2010)

Undoubtedly, the significance of business models and the growing research interest in them is largely determined by their application in business operations. Often, their nature is so original that they constitute groundbreaking innovations in management and competition.

According to Hamel (2002), it is new business models in modern sectors that are more likely to disrupt the old order than the implementation of new ones. In the relevant literature (Zott and Amit, 2013; Knop and Brzóska, 2016; Wirtz *et al.,* 2016; Ritter and Lettl, 2018; Shepherd *et al.,* 2023), the importance of the business model as a key instrument for generating value for the customer and for increasing and maintaining a company's competitiveness is emphasised.

In the relationship between strategies, business models and innovation, one can observe the creation of strategic synergy (Aagaard, 2024) as well as opportunities to develop social and technical architectures and business processes capable of creating new value for both the customer and the company (Prahalad and Krishnan, 2010), which form the basis of competitiveness and resilience.

As noted by Aagaard (2024) and Kubiński *et al.* (2023), changes in business models stem mainly from the requirements of a sustainable economy (development) and the rapid growth of the digital economy and the innovation ecosystem.

In the field of business models, we have various recognised and interesting approaches to value creation (Teece, 2010; Osterwalder and Pigneur, 2010), external antecedents (Brzóska *et al.,* 2022; Höflinger, 2014), the role of development processes (McGrath, 2010), and the importance of the market and customer relationships (Amit *et al.,* 2010), or the role of innovation in the creation and evolution of business models (Teece, 2010; Prahalad and Krishnan, 2010; Brzóska and Knop, 2020; Brzóska, 2014).

In discussions on business models, the close links between a business model and the creation of value for customers and the enterprise through the use of innovation are emphasised (Bocken, Short, Rana and Evans, 2018; Knop and Brzóska, 2020), the role of the configuration of tangible and intangible factors is highlighted, as well as the possibility of capturing a share of the revenue derived from this value (Neft, 2012).

Business model concepts highlight two main dimensions. The first concerns how value is created for the customer in particular: which elements of the business model play a key role here, what role innovation plays (Zott, Amit, Osterwalder and Pigneur, 2010; Bocken *et al.,* 2020) and how this value will be delivered.

The second important dimension of the business model is the capture of value for the enterprise, generating revenue for it. The extent of this value depends largely on the architecture and nature of the resources and activities included in the business model (Casades-Masanell and Ricart, 2010; Brzóska, 2014). It is also important to emphasise their mutual alignment and the level of innovation.

More alignment between the elements of the system of activities leads to an increase in the value created and, consequently, the potential for greater value capture. In turn, a greater scale and diversity of innovation provide opportunities for market success and thus for increasing revenue and profit margins. Examples include business models utilising digital economy tools, start-up models, or sustainable business models (Moratis *et al.,* 2018; Szumniak-Samolej, 2022).

Business models associated with the Economy 4.0 are becoming increasingly significant in developed sectors of the economy (Brzóska and Knop, 2020; Grabowska, 2025). Another aspect of the relationship between innovation and business models is the use of various types of innovation to build model structures and, above all, to create and deliver value to customers. An attribute—and at the same time a result—of applying a business model is the increasingly common occurrence of multidimensional value, i.e., economic, social and environmental value (Schaltegger *et al.,* 2016).

This is intended to meet the customer's needs or enable the resolution of their problems, and, in its highest form, to foster prosumer relationships (a value exchange between supplier and customer). It is also intended to facilitate an increase in the value of the enterprise (Teece 2010; Brzóska and Szmal 2020), primarily through the retention of a portion of the value that constitutes economic value added (EVA), but also through pro-environmental and pro-social initiatives.

The creation of original, multidimensional value (economic, social, economic) that provides a competitive advantage and increases efficiency is linked to innovation, driven by Business Model Innovation (BMI), which is understood as a process aimed at reducing costs, optimising processes, gaining access to new markets or improving financial performance (Foss and Saebi, 2017).

It emphasises not only the importance of product and process innovation but also the component of systemic change, which influences the growth in a company's value, the value proposition for the customer itself, and the process of creating it. The successful implementation of an innovative business model depends on the ability to absorb and subsequently disseminate innovations, which often enable positive transformation and the development of the enterprise (Velu, 2016). The development of an innovative business model is usually driven by changes in the environment, such as the introduction of a new breakthrough technology (Lee *et al.,* 2019) or legal regulations and social conditions.

One such example is the concept of sustainable business models, which brings together a range of approaches that integrate social and economic value into the business model (Moratis *et al.,* 2018). In the broadest sense, a sustainable business model can be understood as a business model whose social and technical architecture, as well as its business processes, focus on creating, delivering and partially retaining value, whilst considering the three key aspects of that value: economic, social and environmental.

Another example of a BMI is the Circular Business Model (Lewandowski, 2016), which constitutes an extension of Osterwalder and Pigneur's classic framework to incorporate the principles of the circular economy (the ReSOLVE methodology).

In turn, Pichlak and Szromek (2022) argue that eco-innovations constitute a central element linking the circular economy with business models and can enhance the competitiveness and efficiency of enterprises, particularly when their implementation is based on symbiosis with the local community, generating social value at both local and global levels. Geissdoerfer, Savaget, Bocken and Hultink (2017) attempted to integrate the concepts of the circular economy and sustainable development, highlighting their importance for building the BMI.

An analysis of the definitions and concepts of business models suggests that we can understand a business model as a configuration (architecture) of processes and project resources that create value for the customer and the organisation. In modern (innovative) business models, multidimensional value (economic, social and environmental) is created through innovation, with digital innovation and sustainable development practices playing a significant role.

Xue *et al.* (2025) demonstrate, using a model-based approach, how the use of big data analytics can help optimise energy use in China. The model developed by the authors helped to prove the hypothesis that the digital economy directly improves energy efficiency. According to the authors, energy consumption is optimised through the modernisation of the industrial structure and supporting scientific and technological innovation in the business sector.

The study conducted by Jiao et al. sets out a research agenda on the relationship between digital technologies and innovation. Although the authors do not formulate any hypotheses based on the bibliometric research carried out, we can observe a very wide range of links between digital innovation and innovation (Jiao *et al.,* 2025).

The impact of digital innovation on business competitiveness cannot be overstated. Leão and da Silva (2021) carried out a systematic review of the literature on this very topic. According to this research, the impact of digital innovation on business competitiveness plays a more significant role than traditional factors of competitive advantage and has positive effects for businesses that implement such innovations.

Among the many studies highlighting the role of digital innovation in helping businesses achieve a competitive position, the research by Vărzaru and Bocean – based on a dataset from the business sector in EU Member States – is particularly noteworthy. The authors confirmed the hypothesis that digital technologies have a positive impact on revenue from innovative activities in EU countries.

Based on information gathered and analysed from European countries, it was also found that digital technologies have a positive impact on all types of innovation, with the most significant impact being on process innovation, communication and logistics chains (Vărzaru and Bocean, 2024).

The literature also describes the 'dark side' of implementing digital technologies in business. This refers to a situation in which digitalisation may have a negative impact on a company's performance rather than improving it, when its costs, management issues or organisational constraints outweigh the benefits.

Kurahmad and Schulz, based on an analysis of selected academic articles, identified five main mechanisms through which digital technologies have a negative impact on companies' performance. These mechanisms are as follows: network dynamics, visual effects and affordances, information asymmetry, disruptive competitive forces and rigidity and flaws of information systems (Kurahmad and Schulz, 2025).

Environmental turbulence, the development of the innovation ecosystem and the digital economy, as well as the requirements of sustainable development, are the key drivers behind the shift in research on business models from relatively simple descriptions of their concepts to complex questions concerning innovation, digitalisation and sustainable development (Ancillai, 2023)

Wirtz *et al.* (2016) having systematised 681 articles, identified four main research strands: business model innovation, business model change and evolution, performance and controlling, and business model design, whilst also identifying these as key areas for future research (Wirtz *et al.,* 2016). The present article falls within the research strand of business model change and evolution.

In turn, Foss and Saebi (2017), summarising fifteen years of research on Business Model Innovation (BMI), pointed out that the literature is fragmented, lacking clarity of concepts, knowledge of the determinants, consequences and processes of BMI. Over the last five decades, the lifespan of a business model has shortened from fourteen to five years. This leads to a situation in which firms must simultaneously exploit their existing business model — to generate current revenue — and explore modified future models that will replace the current one once it becomes obsolete.

This dual pressure, described in the literature as 'organisational ambidexterity', constitutes one of the fundamental challenges of contemporary strategic management. Snihur and Markman, in their review of BMI research published in the

Journal of Management Studies, identify three main pillars around which contemporary literature centres (Snihur and Markman, 2023), the BMI and its determinants; the dynamics of competition between business models – how firms compete not only with products but with the very logics of value creation; and the application of business models in the context of sustainable development and hybrid organisations.

This three-pronged approach indicates that business models have become the intersection of strategic management, innovation and sustainable development. Ancillai *et al.* (2023) conducted a systematic review of the literature on the impact of digital innovations (IoT, AI, blockchain, big data, cloud computing) on BMI, identifying four main thematic areas: (1) data-driven value creation; (2) value delivery via digital platforms; (3) value capture through new revenue models; (4) reconfiguration of value networks.

Meanwhile, Palmié *et al.* (2025) conducted a systematic review of 134 studies from 2007 to 2023 on business models combining digitalisation and sustainability, proposing a framework for digital-sustainable business models Their work identified both numerous complementarities and limitations between the digital and sustainable dimensions of business models, constituting the most recent and comprehensive synthesis of this emerging field of research.

It is within this research context that the subject matter of this article is situated, focusing on the relationship between factors driving changes in business models, such as the use of digital innovations, sustainability and competitiveness, which fall within the research trend on business model change and evolution identified by Wirz *et al.* (2016).

3. Research Methodology

3.1 Research Design

The research methods employed were intended to enable the objectives of the study to be achieved, to answer the research questions and to verify the hypotheses put forward. The research aimed to assess the dynamics of changes in Business Model Innovation in the context of the driving factors behind these changes, selected based on a review of the literature.

The selected factors acting as driving forces for change are the extent of digital innovation adoption, sustainable development practices, and the achievement of competitiveness. A further aim of the study was to identify the relationship between these driving forces of change in the models under investigation and the competitiveness of the enterprises studied. Research on business models in the context of the challenges of the digital and green economy was conducted as part of the SO RIS in PPO – II project to identify changes in the business model in the

materials production and processing sector. The findings presented in the article addressed the following research questions:

RQ1: What kind of digital innovations are companies in the materials production and processing sector introducing?
RQ2: Do sustainability initiatives contribute to increased competitiveness among businesses?
RQ3: Does the level of digital innovation uptake contribute to increased competitiveness?
RQ4: What sustainability initiatives are the companies surveyed undertaking?

The following hypotheses were formulated:

H1: The implementation of digital innovations is a significant factor in the dynamics of change in the business models of companies in the materials production and processing sector.
H2: There is a correlation between the sustainable development initiatives undertaken by companies and their level of competitiveness.
H3: There is a correlation between the level of digital innovation uptake and the competitiveness of businesses.

To achieve the objectives of the thesis, answer the research questions and verify the research hypotheses, a triangulation of research methods was employed, namely quantitative and qualitative methods. The theoretical section of the thesis makes systematic use of a critical review of literature, beginning with classical approaches to business models, moving on to an examination of value, and concluding with BMI.

The research method used was a diagnostic survey, and the research technique was Computer-Assisted Telephone Interviewing (CATI). The questionnaire used consisted of 41 questions relating to the following topics:

General characteristics of the company – 5 questions;
Business model – strategic flexibility and response to change – 19 questions;
Business model – the digital and green economy – 8 questions;
Business model – resilience to crises – 3 questions;
Business model – integration and the future – 6 questions.

The CATI survey was carried out by a company specialising in social research, which holds the Research Quality Certificate – Interviewer Quality Control Programme.

To analyse the dynamics of changes in innovative business models within material production and processing enterprises, composite variables were used:

'Level of digital innovation uptake' (D) – a composite variable comprising the scales described in Table 1
'Competitiveness' (C) – a composite variable comprising the scales described in Table 2
'Sustainability' (S) – a composite variable comprising the scales described in Table 3.

The composite variables set out above are also the driving forces behind changes in the BMI.

The discussion of the answers to the research questions is presented in the empirical section of the thesis. A statistical analysis was also carried out to examine the relationships between the complex variables that constitute the drivers of change in business models.

Table 1. *Characteristics of the composite variable 'level of digital innovation uptake' (D)*

No	Question number	Question	Range of variable
1.	25a	Process digitalisation: Sales and marketing (e.g. online shop, marketing automation, CRM)	[0; 4]
2.	25b	Process digitalisation: Internal operations (e.g. ERP, cloud, workflow)	[0; 4]
3.	25c	Process digitalisation: Customer relations (e.g. chatbots, self-service portals)	[0; 4]
4.	25d	Process digitalisation: Supply chain (e.g. parcel tracking, order automation)	[0; 4]
5.	25e	Process digitalisation: Production systems (e.g. MES)	[0; 4]
6.	26	The use of artificial intelligence (AI) or machine learning (ML)	[0; 3]
7.	28a	Digital and technological adaptability: investment in new technologies	[0; 4]
8.	28b	Digital and technological adaptability: online channels for sales and customer communication	[0; 4]
9.	28c	Digital and technological adaptability: employees' digital skills	[0; 4]
10.	28d	Digital and technological adaptability: data security	[0; 4]
11.	28e	Digital and technological adaptability: new digital tools	[0; 4]
-	-	Composite variable D	[0; 43]

Source: *Own elaboration.*

Table 2. *Characteristics of the composite variable 'Competitiveness' (C)*

No	Question number	Question	Range of variable
1.	17	Scalability of the business model	[0; 4]
2.	18	Cooperation	[0; 3]
3.	19a	Customer focus and innovation: customer research	[0; 4]
4.	19b	Customer focus and innovation: the ability to adapt products or services	[0; 4]
5.	19c	Customer focus and innovation: a culture of innovation	[0; 4]
6.	19d	Customer focus and innovation: rapid testing of ideas	[0; 4]
7.	38	Business Continuity Plan (BCP)	[0; 3]
-	-	Composite variable 'Competitiveness'	[0; 26]

Source: *Own elaboration.*

Table 3. *Characteristics of the composite variable 'Sustainability' (S)*

No	Question number	Question	Range of variable
1.	29	Sustainable development/ESG	[0; 3]
2.	30	Sustainable development initiatives	[0; 6]
3.	32a	Sustainable development: strategy	[0; 4]
4.	32b	Sustainable development: carbon footprint	[0; 4]
5.	32c	Sustainable development: product design	[0; 4]
6.	32d	Sustainable development: benefits	[0; 4]
-	-	Complex variable: Sustainability	[0; 29]

Source: *Own elaboration.*

3.2 Research Sample

The survey involved n=100 companies from the materials production and processing sector operating in Poland. The main areas of activity for these companies were the following divisions of NACE:

22 - Manufacture of rubber and plastic products;
23 - Manufacture of other non-metallic mineral products;
24 - Manufacture of basic metals;
25 - Manufacture of fabricated metal products, except machinery and equipment.

Table 4 shows the size of the general population within the above categories in Poland and Śląskie region.

A random sampling method was used in the study. Each entity meeting the sectoral and regional criteria that was drawn at random from the pool was included in the sample. A sample of n=100 entities was obtained, with 50 entities operating in the Silesian Voivodeship and 50 outside the Silesian Voivodeship.

Table 4. *The general population of enterprises in the materials production and processing sector*

NACE division	number of entities	
	in śląskie region	In Poland
22 - Manufacture of rubber and plastic products	2009	14 710
23 - Manufacture of other non-metallic mineral products	1 989	19 342
24 - Manufacture of basic metals	412	2 065
25 - Manufacture of fabricated metal products, except machinery and equipment	11 061	83 003

Source: *Local Data Bank, Statistics Poland, https://bdl.stat.gov.pl/bdl/*

This sample structure stemmed from the regional nature of the research and the objective of comparing enterprises in the Silesian region with those in other regions. The structure of the sample is set out in Table 5. The entities surveyed include both large enterprises and small and medium-sized enterprises, including micro-enterprises.

Table 5. *Characteristics of the survey sample – type of activity and size of the enterprises surveyed*

company size	NACE divisions				Total
	22	23	24	25	
micro-enterprises	4	8	4	6	22
small enterprises	4	8	10	6	28
medium-sized enterprises	4	6	15	6	31
large enterprises	6	6	3	4	19
Total	18	28	32	22	100

Source: *Own elaboration.*

The data obtained from the quantitative studies were analysed using Statistica 13.

4. Research Results and Discussion

4.1 Level of Digital Innovation Uptake

Table 6 shows the degree of process digitalisation in the business models of the surveyed companies. In the area of sales and marketing (e.g., online shop, marketing automation, CRM), respondents indicated digitalisation 'to a large extent' (32%) and 'to some extent' (26%), suggesting that the approach of partially incorporating digital tools into operations is predominant sales and marketing.

At the same time, there is a noticeable segment of companies with a low level of digitalisation: 16 per cent report no digitalisation ('at all'), whilst 13 per cent each indicate digitalisation 'to a small extent'. However, the distribution of responses indicates that most companies have digitised their processes to a moderate or high

degree (71% in total), suggesting that digital maturity has been achieved in this area.

Table 6. *Level of digitisation of processes in the companies surveyed*

Types of processes	At all not	To a small extent	To some extent	To a large extent	Fully
Sales and marketing (e.g. online shop, marketing automation, CRM)	16	13	26	32	13
Internal operations (e.g. ERP, cloud, workflow)	7	18	39	22	14
Customer relations (e.g. chatbots, self-service portals)	8	13	36	25	18
Supply chain (e.g. parcel tracking, order automation)	6	17	32	23	22
Production systems (e.g. MES…)	7	14	32	29	18

Source: *Own elaboration.*

In the case of internal operations (e.g., ERP, cloud, workflow), the most frequently selected response is "to a moderate extent" (39 per cent), suggesting that in most organisations, internal processes are partially digitised, but a significant proportion of activities remain outside the full digital workflow. 75 per cent of respondents report that their processes are 'halfway' or more digitised.

This indicates the advanced state of these tools' implementation. The digitisation of customer relations (e.g., chatbots, self-service portals) is most often assessed as partial in the surveyed companies: the responses 'halfway' (36 per cent) and 'to a large extent' (25%). This means that customer contact and service are often supported by digital tools, but less frequently constitute a fully digitised, coherent end-to-end process. Most frequently, companies state that supply chain processes (e.g., parcel tracking, order automation) are half-digitalised (32%).

Slightly fewer respondents indicated that digitisation is "largely" (23%) or "fully" (22%) in place, which shows that solutions with a broader scope than just isolated tools are relatively frequently implemented in this area. At the same time, 17% of respondents indicated 'to a small extent', and 6% 'not at all', meaning there is no digitalisation in the supply chain.

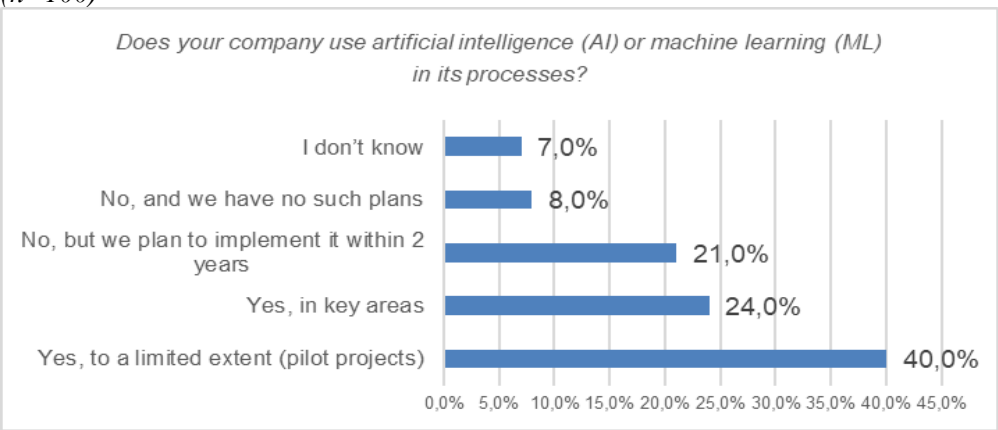
This means that whilst most organisations are at least halfway through the process of digitising logistics and order fulfilment, there remains a significant group of companies at an earlier stage of maturity. The largest number of respondents assess the digitisation of production systems (e.g., MES) as partial: 32% indicate "halfway" and 29% "to a large extent".

This suggests that in many companies, MES-type solutions are implemented to a significant extent, but do not yet cover the entire production process or are not applied uniformly across all areas. The extremes observed across all processes (full

digitalisation versus no digitalisation) are less pronounced than the intermediate categories, which confirms the picture of a transformation being carried out in stages. In summary, the results obtained can be interpreted as a picture of 'advanced transformation in progress':

The use of artificial intelligence (AI) or machine learning (ML) by companies in their processes is illustrated in Figure 1. Companies report using AI/ML to a limited extent scope, mainly in the form of pilot projects (40%).

Figure 1. *The use of artificial intelligence and machine learning in processes (n=100)*



Source: *Own elaboration.*

This indicates that artificial intelligence is already present in practice, but more often as trials and isolated implementations than as solutions systematically integrated into processes. Almost a quarter use AI/ML 'in key areas' (24%), suggesting that some organisations are moving from pilot schemes to applications of operational significance.

Digital adaptability was assessed based on responses to the statements presented in Table 8. Regarding the first statement, responses agreeing with it predominate (52%). This is a sign that, in many organisations, investment in digital innovation is seen as a means of increasing efficiency and business resilience.

Table 8. *Digital and technological adaptability*

Statement	Definitely not	Rather not	Hard to say	Somewhat yes	Definitely yes
1. We invest in new technologies (e.g. the cloud, AI, automation) that boost our efficiency and resilience.	22	11	15	29	23
2. We have a strong digital presence and make effective use of online channels for sales and customer communication.	11	17	21	31	20

3. Our staff have digital skills and are ready to work remotely.	11	18	25	27	19
4. Our data is secure, and the company has a business continuity plan (BCP) in place in the event of a cyber attack or IT failure.	15	9	19	31	26
5. We are quick to adopt new digital tools in response to changing market needs.	12	10	21	28	29

Source: *Own elaboration.*

Some opponents (33 per cent in total) do not see the value of such innovations. The responses are dominated by the belief (held by over half of those surveyed) that companies have a strong digital presence and are able to effectively utilise online channels for sales and communication with customers.

This can be interpreted as a sign that, for a significant proportion of organisations, digital channels have become a genuine business tool, rather than merely a means of enhancing their image.

Respondents tended to rate their employees' digital skills positively (46%), whilst only 11% rated them negatively (statement 3). A relatively large number of companies (57% in total) rate their digital security positively.

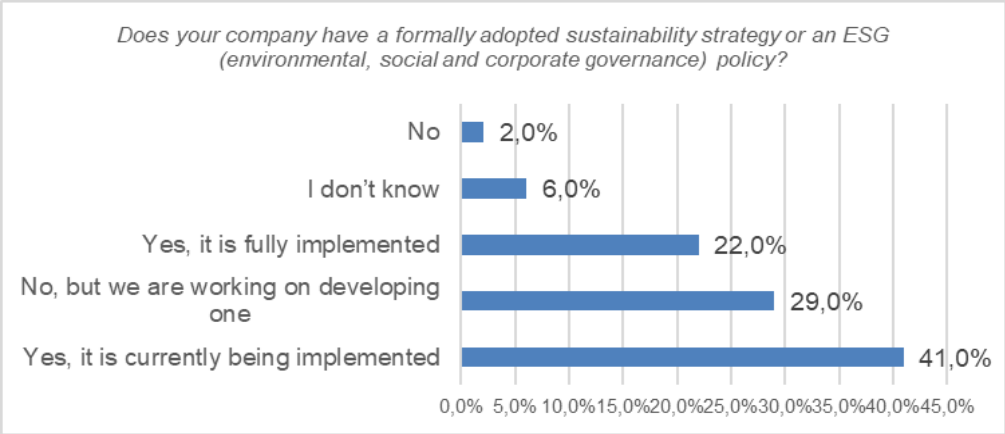
However, nearly a quarter hold the opposite view, which may indicate that the issue of cybersecurity is not being taken seriously enough. Most respondents (57 per cent) are confident in their company's ability to adapt to digital innovations in response to market needs – and thus in the flexibility of their business model – which should be regarded as a positive development.

Sustainability - the scope of sustainable initiatives undertaken Figure 2 shows the responses to the question of whether the company has a formally adopted sustainable development strategy or an ESG (environmental, social and governance) policy (corporate). The largest group of respondents' states that this approach is already in place but is still being implemented: 41% indicate 'yes, it is being implemented', which suggests that, for many companies, ESG is an ongoing process rather than a completed project

Preferences regarding environmental protection measures are shown in Figure 3. The most frequently chosen areas are the circular economy (54.6 per cent), reducing water and material consumption (41.2 per cent) and optimising energy consumption (40.2 per cent). This indicates that many companies are focusing on solutions related to the reuse of resources and waste reduction.

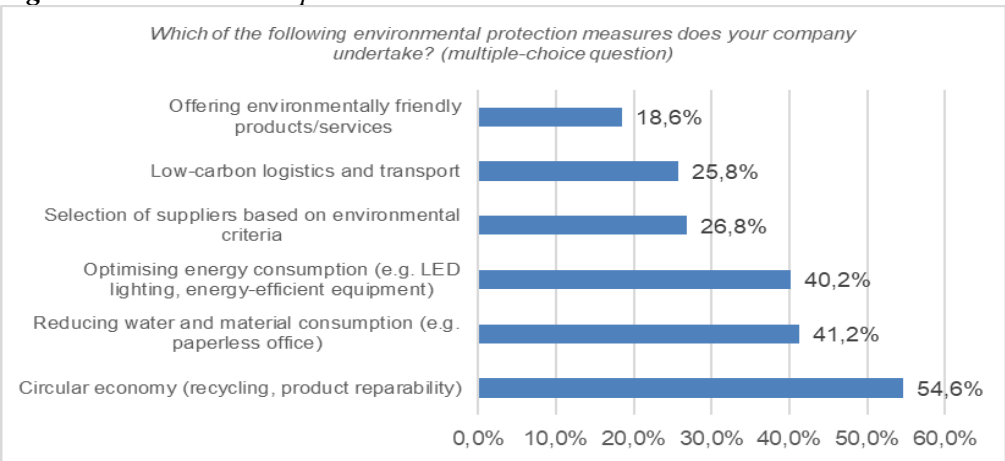
The option receiving the fewest responses was offering products/services of an environmentally friendly nature (18.6%), which may suggest that internal improvements are implemented more frequently than changes to the market offering.

Figure 2. *Sustainable development strategy*



Source: *Own elaboration.*

Figure 3. *Environmental protection measures*



Source: *Own elaboration.*

Opinions on the importance of sustainable development and the circular economy in the business model were obtained through responses to the statements presented, as shown in Table 9.

Table 9. *Sustainable development and the circular economy*

Statement	Definitely not	Rather not	Hard to say	Rather yes	Definitely yes
1. Sustainable development and environmental protection are key elements of our strategy and business model, not merely a marketing ploy.	23	11	13	19	34
2. We are actively reducing our carbon footprint and our consumption of energy and resources.	15	12	18	28	27
3. We design our products/services in line with	12	12	24	33	19

the principles of the circular economy (e.g. reparability, recyclability, reusability).					
4. Our suppliers are also assessed against ESG standards (environmental, social and corporate governance).	15	13	21	26	25
5. We see tangible business benefits (cost savings, new markets, improved reputation) from investing in 'green' initiatives.	15	12	18	30	25

Source: *Own elaboration*

The statement "Sustainable development and environmental protection are key elements of our strategy and business model, not merely a marketing ploy" is endorsed by 53 per cent of respondents, indicating that over half of those surveyed view environmental issues as a genuine component of strategy, rather than merely a public relations exercise. At the same time, there is a significant sceptical group – as many as 34 per cent of respondents – who do not see the strategic importance of environmental protection.

On the other hand, over half of the respondents support measures to reduce carbon dioxide emissions and resource consumption, which is a positive development for the sector under review. When assessing the statement 'We design our products/services in line with the principles of the circular economy (e.g. reparability, recyclability, reusability)', positive opinions prevailed (52 per cent), which means that in more than half of the companies, a circular approach is present in their thinking about product design.

At the same time, the relatively high proportion of 'hard to say' responses (24 per cent) may indicate that the principles of the circular economy are not yet clearly defined in the design process or are poorly communicated within the organisation. Positive responses predominate in statement 4, suggesting that in around half of the companies, ESG factors are incorporated into the assessment or selection of suppliers.

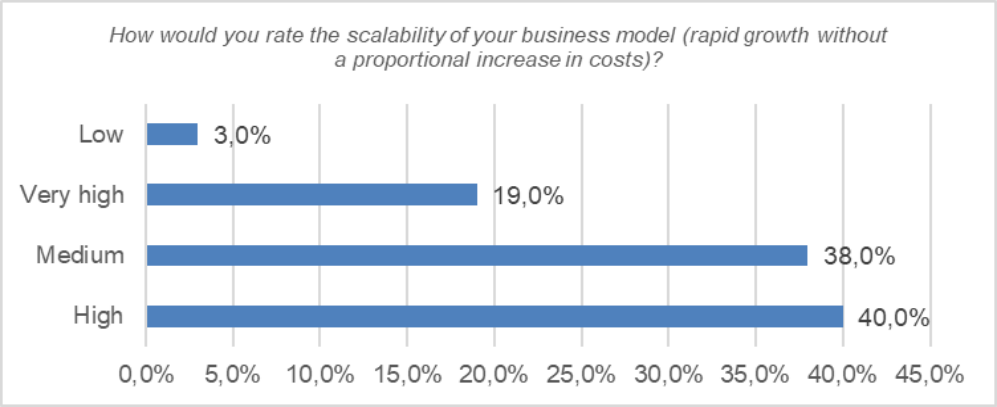
Respondents were asked to rate their level of agreement with the statement: "We see tangible business benefits (cost savings, new markets, improved reputation) from investing in 'green' initiatives." Agreement was most common: 30% selected "I tend to agree", and 25 per cent chose 'strongly agree', which together amounts to 55 per cent and suggests that, for more than half of the companies, pro-environmental investments make tangible business sense, rather than being merely for the sake of image.

4.2 Competitiveness

The assessment of a business model's scalability is clearly positive in the sample surveyed, with 'high' and 'medium' responses predominating, as shown in the

figure. The largest proportion of respondents' rate scalability as high (40 per cent), and almost as many as medium (38 per cent). Nineteen per cent of companies report a very high capacity for scaling, whilst only 3 per cent report a low capacity. This distribution indicates that a total of 59% of companies perceive their model as at least highly scalable (high + very high), whilst the marginal proportion of low ratings suggests that barriers to scaling are not directly recognised as a dominant problem within the sample.

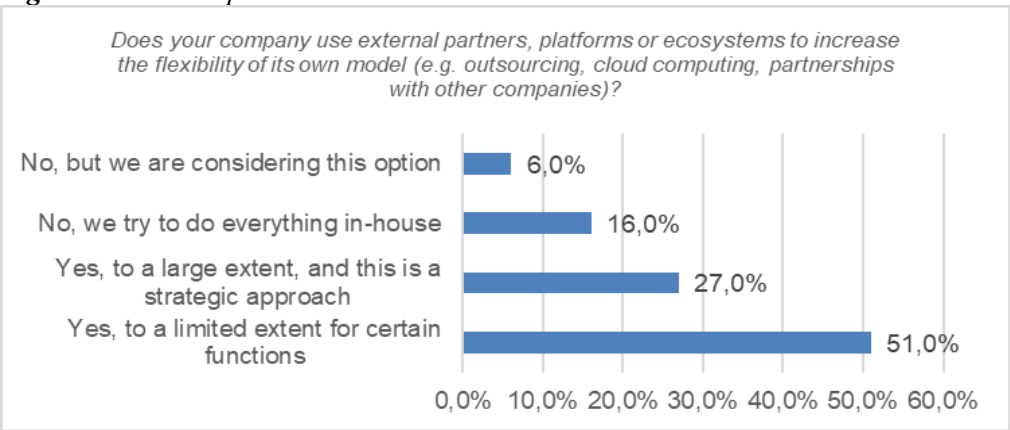
Figure 4. *Scalability of the business model*



Source: *Own elaboration.*

The use of external partners, platforms or ecosystems (e.g., outsourcing, the cloud, partnerships with other companies) is a common phenomenon in the sample, although it is most often limited to selected functions. The distribution of responses suggests that, for most companies, the flexibility of the business model is enhanced by 'hybrid' solutions (combining in-house and external resources), whilst the full internalisation of functions remains a minority approach.

Figure 5. *External partners*



Source: *Own elaboration.*

Opinions on customer orientation and innovation were obtained through responses to the statements presented, as shown in Table 10.

Table 10. *Digital and technological adaptability*

Statement	Definitely not	Rather not	Hard to say	Somewhat yes	Definitely yes
1. We regularly assess our customers' changing needs and expectations.	31	7	15	20	27
2. We are able to quickly adapt our products or services to meet new customer needs.	14	15	21	28	28
3. Our company culture encourages innovation, experimentation and learning from mistakes.	21	10	26	25	18
4. We closely monitor market trends and our competitors' activities.	14	18	23	18	27
5. We have a well-established process for quickly testing and implementing new ideas (e.g. the lean start-up methodology).	19	12	16	29	24

Source: *Own elaboration.*

Regarding the finding concerning regular surveys of changing customer needs and expectations, the distribution of responses indicates a clear polarisation. The largest group of respondents strongly disagrees that their company conducts such regular surveys (31 per cent), whilst a further 7 per cent tend to disagree, giving a total of 38 per cent of negative responses. Conversely, 27% of respondents strongly state that they regularly survey customer needs and expectations, whilst 20% tend to confirm this (a total of 47% of positive responses).

The overall picture of the response's points to two operating models: the systematic collection of customer information and a more intuitive or ad hoc approach. Statements regarding the ability to quickly modify products or services in response to new customer needs paint a moderately positive picture, though with a clear element of uncertainty. Responses confirming this ability total 50% (28% 'I tend to agree' and 22% 'I strongly agree').

On the negative side, a total of 29 per cent of respondents indicate that their company is unable to modify its offering quickly (15 per cent 'tend to disagree' and 14 per cent 'strongly disagree'). The proportion of 'hard to say' responses (21%) also remain significant, which may suggest that in some companies the pace and effectiveness of changes are not measured or described in an unambiguous manner, or depend on the specifics of a particular project and are therefore difficult to generalise at company-wide level.

The assessment of organisational culture as a factor fostering innovation,

experimentation and learning from mistakes is ambiguous in the sample surveyed, with a high proportion of undecided responses. The most frequently selected category is 'hard to say' (26 per cent), which represents the largest single proportion.

On the positive side, a total of 43 per cent of respondents' state that their company's culture encourages innovation and learning from mistakes (25% 'I rather agree' and 18% 'I strongly agree'). Negative responses account for a total of 31% (21% 'I strongly disagree' and 10% 'I rather disagree'). This distribution suggests the coexistence of at least two distinct organisational experiences: a subset of companies where a pro-innovation climate is reported, and a significant group where the organisational culture is not perceived as supportive of experimentation.

At the same time, the high level of uncertainty may indicate a lack of clear practices and standards regarding experimentation (e.g., a lack of formalisation, inconsistent experiences across different departments) or that respondents are assessing the company's culture through the prism of individual situations which do not form a coherent picture. The distribution of responses relates to the statement: 'We closely monitor market trends and competitors' activities', i.e. the declared practice of systematically tracking the market environment and competitors' activities.

The most frequently selected response is 'I strongly agree' (27%), which indicates that for a significant proportion of companies, market monitoring is a clearly recognisable element of their modus operandi. At the same time, there is a high proportion of 'hard to say' responses (23%), which may suggest that in some companies, monitoring is carried out in a way that is not very transparent (e.g. in selected departments) or is informal and is therefore not clearly recognisable to those completing the survey.

The intermediate responses are distributed symmetrically: 'I somewhat agree' and 'I somewhat disagree' each account for 18 per cent, indicating variation in the intensity of this practice and the absence of a single standard within the sample. On the negative side, 14 per cent of respondents 'strongly disagree', i.e. they explicitly state that there is no close monitoring of trends and competitors.

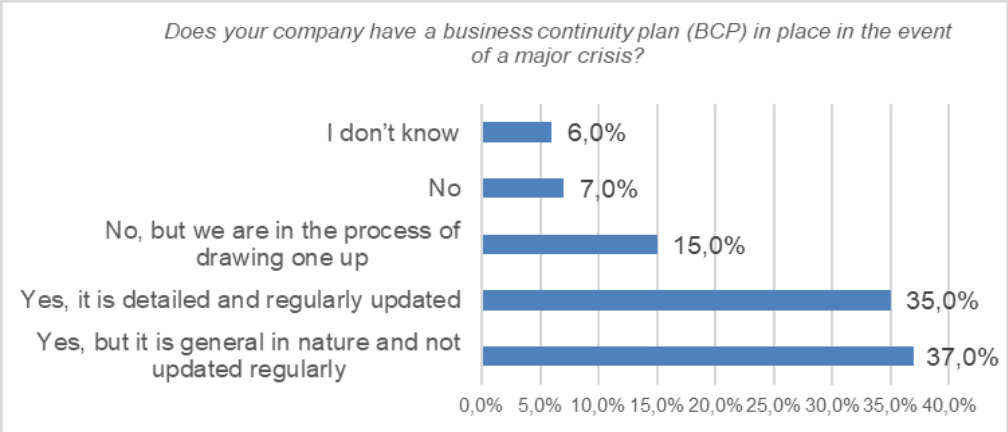
Overall, responses confirming monitoring (45 per cent) are more common than those denying it (32 per cent), whilst there is a significant proportion of uncertainty (23 per cent), which indicates that market monitoring is a moderately widespread but unevenly established practice within the surveyed companies. In the case of the statement: "We have a process in place for quickly testing and implementing new ideas (e.g. the lean start-up methodology)", the most frequently selected response is "I somewhat agree" (29%), followed by "I strongly agree" (24%), which together account for 53% of responses confirming the existence of such a process.

On the negative side, 19 per cent of respondents "strongly disagree" and 12 per cent "somewhat disagree", meaning that a total of 31 per cent of companies do not

confirm having a process in place for the rapid testing and implementation of ideas. In addition, 16% indicated "it's hard to say", which may mean that in some companies, innovative activities are carried out in an unsystematic manner, depend on specific individuals or projects, or are not sufficiently formalised for the respondent to unequivocally describe them as a "process".

In summary, the results indicate a moderately positive assessment of activities related to customer focus; the declared potential for innovation is rated highly, whilst the use of organisational culture to support pro-innovation activities is rated less favourably.

Figure 6. *Business continuity plan in enterprises*



Source: *Own elaboration.*

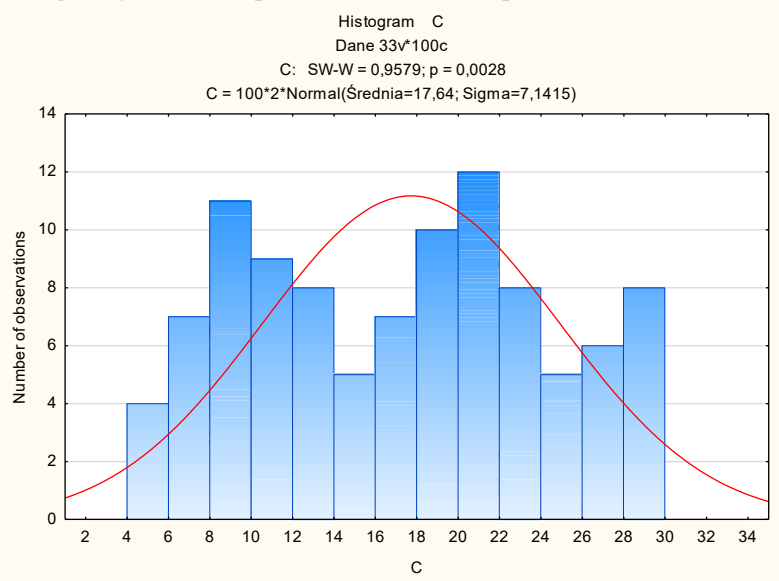
One element of maintaining competitiveness is a business continuity plan (BCP). Research shows (Figure 6) that it is present in companies, but often at varying levels of maturity. The largest group indicates that a BCP exists, but that it is of a general nature and is not regularly updated (37 per cent), which may mean that the document is in place but is not systematically tested in practice or adapted to new risks.

At the same time, 35% of respondents state that their company has a detailed BCP and updates it regularly. This suggests the existence of a sizeable group of organisations that treat business continuity as a process (involving reviews, tests and adaptation to changes), rather than a one-off exercise in drawing up a document.

The relationships between the driving forces of business model change. As part of the research, three composite variables were defined, which were also regarded as key drivers of change in the business model: Level of digital innovation uptake (D), Sustainability (S), Competitiveness (C). Each of the variables consisted of the simple variables described in the 'Research Design section. Before determining the relationships between the composite variables, we examined whether the variables were normally distributed. For the 'Competitiveness' variable, a histogram was

produced (Figure 7) and the Shapiro-Wilk statistical test was carried out.

Figure 7. *Histogram for the composite variable 'Competitiveness' (C)*



Source: *Own elaboration.*

For the variable measuring the level of competitiveness, the Shapiro-Wilk test statistic is 0.9579 and, at a confidence level of p = 0.0028, we can conclude that there is a statistically significant deviation from a normal distribution.

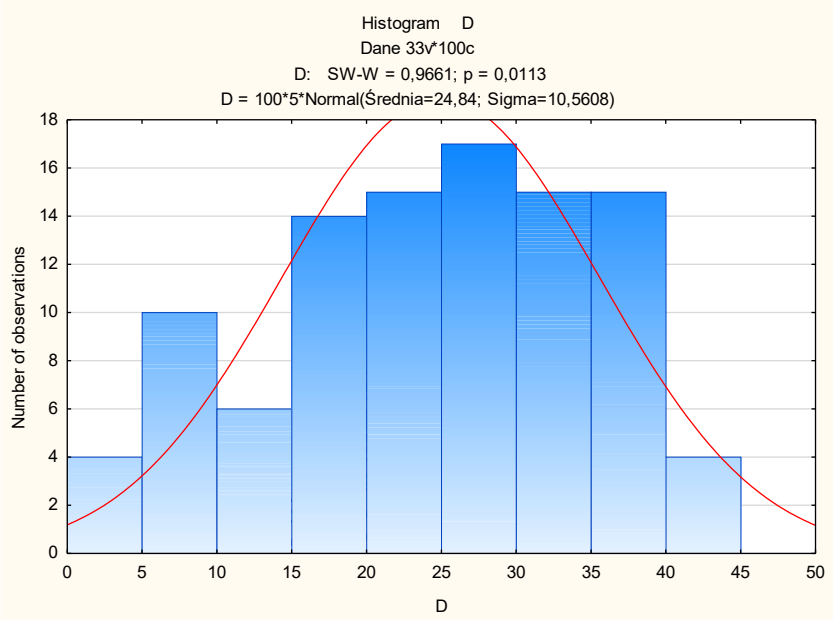
Despite the high-test statistic (close to one), the distribution is not normal because the confidence level is significantly lower at α = 0.05. This is also evident from the histogram, where we observe three peaks: the first around values of 8 to 10, the second around values of 22–24, and the third around values of 28–30.

The second of the composite variables analysed, 'level of digital innovation uptake', consisted of 11 specific questions. This variable was also analysed for normality of distribution. Figure 8 shows a histogram together with the Shapiro-Wilk test values.

For the level of digital innovation adoption D, the Shapiro-Wilk test statistic is high, at 0.9661; however, more importantly, the confidence interval at p = 0.0113 is below the standard significance level α = 0.05. We cannot conclude that the distribution for this composite variable is normal.

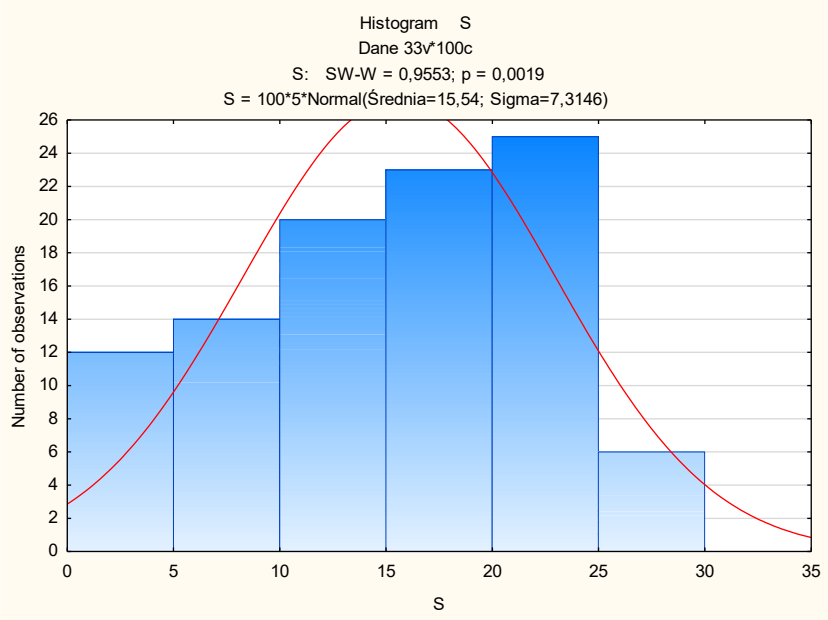
For the last of the analyzed variables, Sustainability (S), the Shapiro-Wilk test also indicated that the variable does not follow a normal distribution (Figure 9). The test statistic SW-W = 0.9553 and the significance level p = 0.0019 are significantly lower than the standard significance level α = 0.05.

Figure 8. *Histogram for the composite variable 'level of digital innovation uptake' (D)*



Source: *Own elaboration.*

Figure 9. *Histogram for the composite variable 'sustainability' (S)*

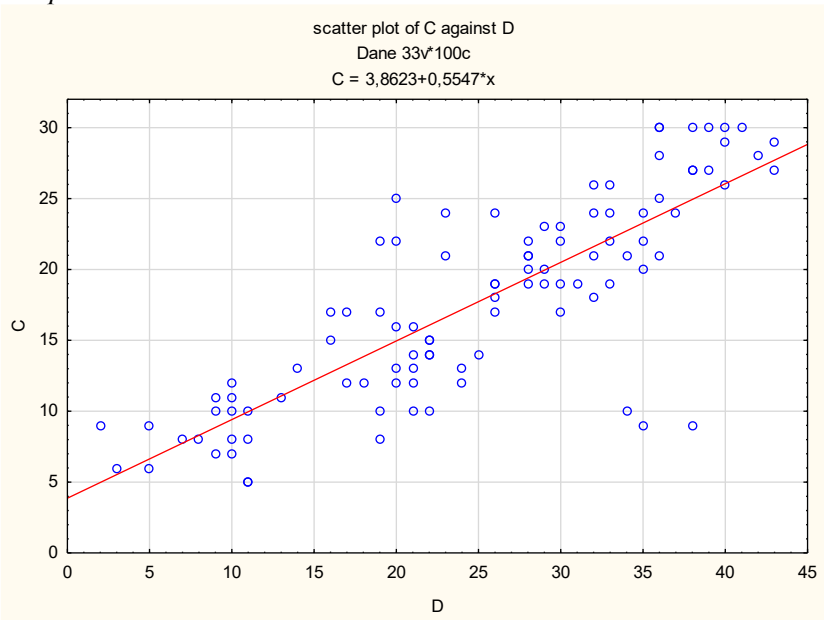


Source: *Own elaboration.*

As none of the composite variables used (D, S, C) follow a normal distribution,

Pearson's test cannot be used to analyse the correlations between these variables. Consequently, the relationships between the variables were presented in scatter plots and a Spearman's rank correlation test was carried out.

Figure 10. *The relationship between variables D 'level of digital innovation uptake' and C 'competitiveness'*



Source: *Own elaboration.*

The chart in Figure 10 shows a positive correlation between the level of adoption of digital innovations and competitiveness. The wider the scope of application of digital innovations within companies, the higher the perceived level of competitiveness.

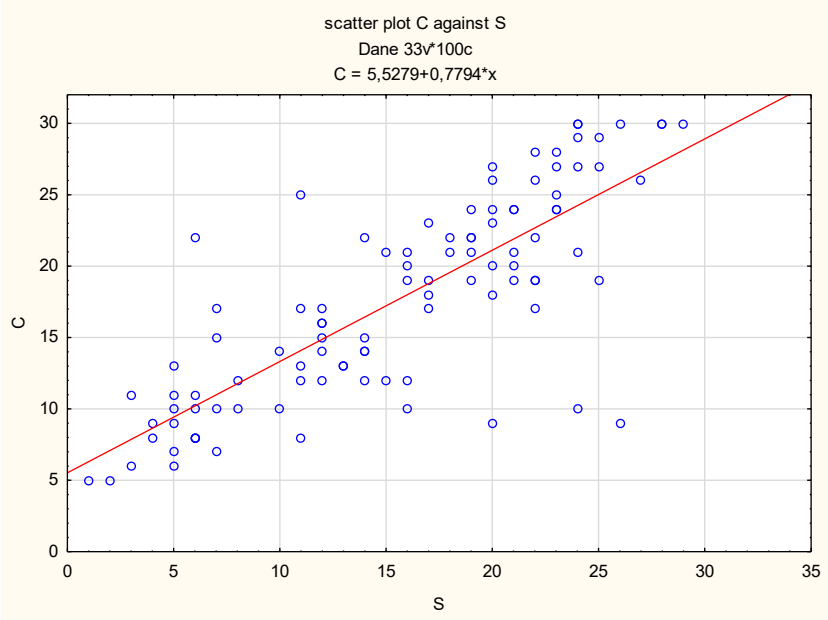
Figure 11 illustrates the relationship between the variables, determining the level of sustainable activities and competitiveness. The link between sustainable initiatives and business competitiveness is direct and synergistic. Investments in sustainable development, often referred to as eco-innovations, transform environmental costs into a lasting competitive advantage.

The growing scope of these initiatives translates into tangible market and operational benefits. It should be noted, however, that some environmental measures may entail higher costs for businesses. This applies, for example, to sourcing certified 'green' raw materials from suppliers who meet high environmental standards. For these reasons, we expected that the relationship between sustainability and competitiveness might not be straightforward.

One factor pointing to the existence of a positive relationship between sustainability

and competitiveness is the strengthening of companies' competitive position vis-à-vis customers who expect a high level of sustainability. However, the correlation S - C is positive and can be seen in the graph. The greater the extent of sustainable initiatives undertaken, the higher the perceived level of competitiveness of the companies.

Figure 11. *The relationship between variables S 'sustainability' and C 'competitiveness'*



Source: *Own elaboration.*

The final relationship analysed in the scatter plot (Figure 12) is that between the level of digital innovation uptake and the sustainability of the enterprises under study. This relationship does not seem obvious. The relationship between the extent to which digital innovations are utilised and the scope of sustainable activities is mutually reinforcing.

Digital innovations are a key enabler for achieving sustainable development goals, whilst environmental challenges often spur further technological innovation. Technologies such as artificial intelligence (AI), the Internet of Things (IoT) and cloud computing are automating data analysis. This enables companies to monitor their energy, water and raw material consumption precisely and reduce it significantly.

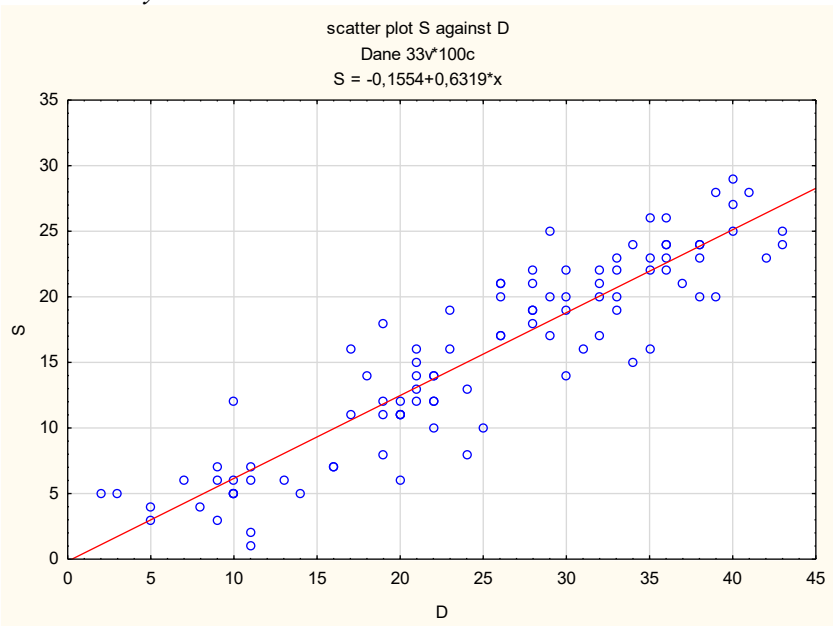
Advanced software facilitates the collection and processing of vast amounts of data. This enables businesses to meet stringent legal requirements (such as the EU's CSRD Directive) and to report transparently on their environmental and social

impact. Digital technologies also support eco-design and enable the tracking of products throughout their entire life cycle, which results in less waste and better use of recycled materials.

Companies with a high level of digitalisation implement green technological innovations more effectively, which directly translates into better performance around corporate social responsibility (CSR).

In fact, it is difficult to identify a phenomenon that would have a negative impact on the relationship between the level of adoption of digital innovations and sustainability. As a result, we can observe a positive correlation between the variables S and D.

Figure 12. *The relationship between variables D 'level of digital innovation uptake' and S 'sustainability'*



Source: *Own elaboration.*

Table 11. *The values of the Spearman's rank correlation test between variables D, S and C.*

	C	D	S
C	1,000000	0,807565	0,782786
D	0,807565	1,000000	0,910814
S	0,782786	0,910814	1,000000

Source: *Own elaboration.*

The test results show high positive values for Spearman's rank correlation test for p

< 0.05. Based on this test hypotheses 2 and 3, concerning the existence of a relationship between the level of adoption of digital innovations and competitiveness, and between sustainability and competitiveness, have been verified.

The results obtained in this study confirm those of Xue *et al.* (2025), the digital economy and digital innovation are fundamental and direct tools for improving energy efficiency at both the macroeconomic and microeconomic levels, i.e., at the level of individual enterprises.

When comparing the findings with those of Jiao *et al.* (2025), links between innovation and digital technologies are also evident. In the case of the manufacturing firms studied, these are primarily digital tools supporting production processes, but also logistics and marketing processes.

The findings also corroborate those of Leão and da Silva (2021), who employed bibliometric analyses to highlight the role of digital innovation in achieving competitive advantage. The empirical research presented in our article demonstrates a direct correlation between digital innovation and competitiveness and also shows the deliberate use of digital innovation within the business sector to gain a competitive advantage.

When comparing the results obtained here with the research presented by Vărzaru and Bocean (2024), it should be noted that the studies presented in this article did not include, for the purposes of analysis, the innovation revenues analysed by Vărzaru and Bocean. In our analyses, we focused on a composite competitiveness variable, which did not consider financial performance or measures of competitive position such as market share or market share growth at all.

However, the relationship between the adoption of digital innovations and competitiveness was confirmed, which is consistent with the hypotheses of Vărzaru and Bocean's study.

In the present study, we found no evidence of a 'dark side' to digitalisation, as discussed in the literature, for example in the research by Kurahmad and Schulz (2025). This may be linked to the fact that the adoption of digital technologies is still in its early stages, with the benefits currently outweighing the costs. Negative phenomena observed in the business world, such as digital burnout, tend to affect employees rather than the organisation, and we did not observe any manifestations of these phenomena, for example, in open-ended or semi-open-ended questions. The study did not identify any of the mechanisms described by Kurahmad and Schulz.

5. Conclusions

An analysis of the responses regarding the driving force behind the level of digital

innovation uptake allows the following conclusions to be drawn:

- One of the three most used digital innovations is the digitisation of business processes, particularly tools such as systems for digitising production processes using an MES module, which as many as 79 per cent of the surveyed companies use either fully or in part. This situation can be explained by the nature of the production activities carried out by the surveyed companies.
- The same proportion of respondents (79%) use digital innovations in the supply chain, which enable the tracking of consignments, the automation of orders and, consequently, the streamlining of logistics – a factor that is crucial for manufacturing companies.
- In the area of customer relations, 79% of companies also state that they use digital innovations such as chatbots and self-service portals, which demonstrates their appreciation of marketing innovations.
- A slightly lower proportion – 75 per cent – of respondents utilise digitalisation of internal operations such as ERP, cloud computing and workflow systems, which are linked to production processes; thus, here too, we observe the syndrome of the production-oriented nature of the companies surveyed.
- There is considerable interest amongst respondents in artificial intelligence (AI), which is used by 64 per cent of them, 24 per cent of whom use it in core business processes. It should be added that a further 21 per cent intend to use it, whilst only 8 per cent have no such plans. It can be assumed that the use of AI in businesses will continue to grow rapidly.
- More than half of companies are investing in digital technologies, adopting digital innovations and stating that they are digitally resilient and secure. Only 19 per cent of companies say that their staff possess digital skills, which may be a significant barrier to the further implementation of digital innovations.
- To summarise, the findings of the research in this area demonstrate a high degree and scope of digital innovation adoption, and the information presented answers the first research question (RQ1).

In turn, the responses provided regarding driving force ‘sustainability – the scope of sustainable initiatives undertaken’ allow us to draw the following conclusions:

- Twenty-two per cent of the companies surveyed have adopted a sustainable development strategy or an ESG policy, whilst as many as 40 per cent are in the planning stage and 24 per cent are working on one; taken together, this means that 88 per cent of companies recognise its importance. This trend should be viewed positively, as it promotes the development of a sustainable economy.
- The most prominent environmental protection measures are the circular economy (54.6 per cent), reducing water and material consumption (41.2 per

cent) and optimising energy consumption (40.2 per cent). This is the response to the fourth research question (RQ4), which indicates a focus on solutions related to the reuse of resources and waste reduction. Few companies – just 18% – endeavour to offer eco-friendly products, which points to a low level of eco-friendly product innovation.

- More than half of companies regard sustainability as a key element of their business model and strategy; they see tangible benefits in it, reduce their energy consumption and carbon footprint, and assess their suppliers against ESG standards. This reflects a growing awareness of sustainability within the business community.

The conclusions drawn from the analysis of the 'competitiveness' variable were formulated as follows:

- A total of 59 per cent of companies rate the scalability of their business model as 'very high' or 'high', which demonstrates their confidence and potential for growth; this is therefore a positive development.
- Cooperation, which is currently an important factor in competitiveness, is reported by 78 per cent of respondents, of whom only 27 per cent engage in it to a significant extent, whilst 16 per cent report a lack of it. Given the manufacturing nature of the respondents' businesses, these findings are not surprising.
- Research into customer focus and innovation indicates that over half of those surveyed cited the ability to quickly adapt products to customer needs (56 per cent) and the implementation of new ideas (53 per cent). Performance is weaker (below 50 per cent) in areas relating to the analysis of customer needs and market trends; and, surprisingly, the extent to which culture influences innovation is low, with only 43 per cent seeing a positive correlation. This points to a need to develop human capital in the field of innovation.
- One of the key elements in maintaining competitiveness is a business continuity plan (BCP). Research indicates a positive situation in this regard, as 87 per cent of the companies surveyed either have such a plan or are in the process of drawing one up, whilst only 7 per cent do not have such a document.

An analysis of the research findings confirmed that there is a statistically significant correlation between sustainable initiatives and competitiveness. This relates to the second research question (RQ2). The article sets out arguments that suggest sustainable initiatives (S) have an impact on competitiveness (C).

The research findings provide a positive answer to the third research question (RQ3), there is a statistically significant correlation between the level of digital innovation uptake (D) and competitiveness (C). Detailed descriptions of the results suggest that it is the level of digital innovation (D) that affects competitiveness (C).

Arguments have been put forward to support the first hypothesis (H1) The implementation of digital innovations is a significant factor in the dynamics of change in the business models of companies in the materials production and processing sector. Hypothesis H1 has been confirmed.

Hypotheses H2 and H3 were confirmed using Sperman's rank correlation test, at a significance level of $\alpha = 0.05$.

The research limitations of this study stem from the relatively small sample size – the study is regional in nature, with reference to an equally sized sample of enterprises outside the region. Despite the statistical significance of the tests used, no statistical analysis of the reliability of the studies was carried out as part of the analysis of the results. Sampling errors may occur in research which could affect the results obtained.

A further limitation of the research is the declarative nature of the respondents' responses. It is not possible to verify the accuracy of the responses provided.

However, respondents were guaranteed anonymity; they had no incentive to present their businesses in a better light than they are.

The research findings can be used to streamline industrial policy, particularly at regional level, with a view to improving BMI support measures.

The diagnostic and statistical analyses carried out, the answers to the research questions, and the verified hypotheses allow us to conclude that there have been significant changes in the BMI of the companies studied. The assessment of the rate of change is based on the impact of three driving forces: level of digital innovation uptake, sustainability and competitiveness; this should be regarded as the fulfilment of the objectives of the work.

Acknowledgments: *The publication of this article was funded by the project 'Developing the potential of Silesian biomedical engineering in the face of the challenges of the digital and green economy' (BioMeDiG) carried out at the Silesian University of Technology.*

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