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ARTIFICIAL INTELLIGENCE ADOPTION CHALLENGES IN THE SMALL AND MEDIUM-SIZED ENTERPRISE SECTOR: A COMPARATIVE ANALYSIS OF POLAND, GERMANY AND DENMARK

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Abstract

Background and Objective: Recognising the vital role of SMEs in driving economic growth and the uneven AI adoption levels across EU countries, this article explores AI adoption within SMEs in Poland, Germany and Denmark, highlighting the barriers they face. The study aims to enhance understanding of the factors that hinder SMEs from adopting AI technology. Recognising and addressing these challenges is essential for SMEs to succeed.

Materials and Methods: The study compares AI adoption in the SME sectors of Poland, Germany and Denmark within the EU context, focusing on the barriers and challenges. The article synthesises cross-country evidence from prior empirical studies and statistics drawn from Eurostat databases and the Digital Economy and Society Index.

Results: Internal capabilities are the strongest predictors of AI adoption, and environmental support is helpful only when institutions are mature. Barriers typically cluster, with varying intensity, around data availability and quality, skills gaps, costs, integration with legacy systems, privacy, and cultural resistance. The article consolidates scattered EU evidence into an accessible benchmark and offers country-specific recommendations to boost SME AI adoption.

Practical implications: The article provides insights that can support entrepreneurs in successfully integrating AI technologies. It is also helpful for policymakers to promote AI adoption, thereby boosting the competitiveness of small and medium-sized enterprises.

Conclusion and summary: The gap in AI adoption is closely linked to the overall level of digitalisation, and limited digital infrastructure in the economy hampers the deployment of AI solutions in the SME sector. AI programmes for small and medium-sized enterprises need to be tailored to each country's level of adoption.

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1. Introduction

Small and medium-sized enterprises (SMEs) account for 99.8% of all businesses (European Commission, 2024b), and their contribution to economic growth is broadly recognised. The integration of digital technologies and artificial intelligence in SMEs is now essential rather than optional, as it is vital for remaining competitive and adapting to the constantly changing business environment (Brodny & Tutak, 2022). Compared to larger organisations, SMEs are notably underrepresented (Aarstad & Saidl, 2019), which is a missed opportunity (Singh, 2024).

There is still limited understanding of the challenges organisations face when implementing AI in their operations, and, as a result, limited guidance on how to enhance an organisation's AI maturity to achieve value (Holmström, 2022). The study of literature on the effect of AI on SMEs highlights its potential to improve efficiency, competitiveness, customer experience, and sustainability in areas such as finance, marketing, and human resource management (Habibi & Zabardast, 2020; Hansen, E. & Bøgh, S., 2021; Kandeel et al., 2024; Peretz-Andersson et al., 2024). Given the potential benefits of AI for SMEs, this paper aims to advance the current state of the art by providing a clearer understanding of the constraints to AI adoption across EU countries at different stages of AI adoption. To achieve this goal, two research questions will be addressed.

1. What is the current state of artificial intelligence adoption among SMEs in Poland, Germany and Denmark compared to other EU countries?
2. What obstacles and difficulties do Polish, German and Danish SMEs encounter when adopting AI technologies?

The study identifies the most common obstacles and those specific to each country at different stages of AI adoption. It provides actionable insights to help small and medium-sized enterprises overcome AI adoption barriers. Entrepreneurs can use these findings as a diagnostic tool to assess their readiness and develop targeted strategies for successful AI implementation. It is also helpful for policymakers to promote AI adoption, thereby increasing the competitiveness of small and medium-sized enterprises. The article expands the TOE framework, a leading theory in technology adoption research. It provides empirical evidence that organisational (internal) capabilities are stronger predictors of AI adoption than external factors. Moreover, the study combines insights from Resource Dependency Theory, emphasising that AI adoption depends on firm-specific capabilities and complementary assets; Institutional Theory, showing that regulatory and cultural environments

influence adoption readiness; and Innovation Diffusion Theory, by linking adoption stages to national digital intensity levels. This multi-theoretical approach enhances existing models and contributes to a more comprehensive theory of AI readiness in SMEs. It therefore enhances the theoretical understanding of how SMEs adopt AI across various institutional contexts, laying a foundation for future empirical and policy-focused research. The study shows that improving AI adoption in SMEs can increase innovation, efficiency and competitiveness. Since SMEs make up 99.8% of EU enterprises, even small gains in AI adoption can significantly boost productivity and GDP. By comparing Poland, Germany and Denmark, the paper identifies digital divides within Europe. Addressing these can reduce economic disparities between EU regions, supporting more balanced development.

The study is divided into four sections. The first section is the introduction. The second section reviews the literature on theories explaining AI adoption, as well as the barriers and challenges that small and medium-sized organisations encounter when implementing AI. Because the pace of AI adoption varies across EU member states (Husillos, 2024), the third section presents a comparative analysis of how SMEs in Poland, Germany and Denmark – each at different stages of AI adoption – are implementing AI technologies, and the obstacles they face. The final section summarises the paper and offers recommendations for countries at various levels of AI adoption.

2. Literature review

There has been an increase in research exploring how artificial intelligence affects the performance, efficiency and competitiveness of enterprises (Arroyabe et al., 2024; Oldemeyer et al., 2025; Peretz-Andersson et al., 2024; Schoeman & Seymour, 2022). Overall, studies agree on three main themes: (i) AI can boost growth and innovation, (ii) the benefits seen depend heavily on complementary assets (such as data, digital infrastructure, skills, and governance), and (iii) evidence is mixed, with adoption barriers and measurement difficulties influencing observed outcomes.

Multiple factors influence how SMEs adopt AI technologies, and theories explain AI adoption within various contexts. One of these is the TOE framework, a well-established theoretical model that has been widely discussed in recent academic literature (El-Haddadeh, 2020; Nguyen et al., 2022; Schwaeke et al., 2024; Mathagu, 2024). Using the TOE framework, researchers can better understand the factors that facilitate or hinder AI adoption, and pinpoint research areas that promote a culture of innovation and technological progress in SMEs. The TOE model suggests that adopting new technology relies on three main factors: technology, organisation and environment (Awa et al., 2017). It also offers valuable insights into the internal and external elements influencing the decisions of organisations to adopt technology (Hossain & Quaddus, 2012). Following the TOE model, Schwaeke et al.

(2024) analysed 106 peer-reviewed articles on AI adoption in SMEs and categorised the states and trends into eight clusters. In the realm of technology, they found compatibility and infrastructure; in the realm of organisation, they identified knowledge, resources and culture; and in the realm of environment, they highlighted competition, regulation and the ecosystem. This research confirmed that successful AI adoption depends on aligning existing practices and cultures, addressing customer needs, and considering potential challenges such as financing, resistance, compatibility, complexity, and legal issues.

Another concept, Resource Dependency Theory (Hofer et al., 2012), offers insights into how external resources and environmental factors influence AI adoption processes. Arroyabe et al. (2024), drawing on resource dependency theory and dynamic capabilities theory, conducted an empirical study involving more than 12,000 SMEs from the European Union and examined both the support provided by the European ecosystem to SMEs for AI adoption, and the internal resources of SMEs. Their results highlight that internal digital and innovation capabilities have a greater impact on AI adoption in SMEs than business environmental support. It suggests that capability gaps, not just a lack of access to technology, limit SME benefits. Ardito et al. (2025), drawing on resource dependency theory, investigated the relationship between AI adoption and revenue growth in European SMEs. They also assessed the combined effect of AI, the Internet of Things, and Big Data Analytics. Their findings show that AI fosters SME growth, especially when used together with IoT and BDA.

Institutional theorists claim that the decisions of organisations to adopt technology are not solely about innovation but mainly about responding to various institutional pressures in their competitive environments (Bag et al., 2021). These institutional forces often create pressures or industry trends that push or influence organisations to pursue innovation initiatives (Jiao et al., 2022). An organisation's drive for innovation is shaped not only by internal evaluations, as commonly noted in existing innovation literature, but also by complex external factors such as network ties (Albats et al., 2022). According to Chen & Filieri (2025), institutional forces play a significant role in shaping technology adoption among small organisations.

Innovation Diffusion Theory explains how new technologies spread within a population or system over time. This theory can be seen as a foundation for understanding how and why SMEs decide to implement AI. Studies (Sánchez et al., 2025) show that compatibility is the most significant predictor of AI adoption in SMEs. Effective implementation of artificial intelligence solutions requires developing and adopting complementary technologies that produce synergistic effects. Multiple studies highlight that the impact of AI effects depends on complementary assets. A high level of digitalisation is a key factor enabling AI implementation, while insufficient digitalisation in SMEs hinders its deployment (Bettoni et al., 2021; Cubric, 2020). Peretz-Andersson et al. (2024) show in Nordic SME cases that value reali-

sation relies on resource orchestration, such as skills, data governance, and process redesign, rather than tools alone.

Another perspective is presented by Segarra-Blasco et al. (2025), who studied the adoption of AI in European SMEs and stated that the most likely adopters of artificial intelligence technologies are:

— Scale-ups and start-ups. These firms are inherently innovative and are among the most likely to adopt AI. They are flexible and respond to market shifts (Hajoary et al., 2024). Additionally, start-ups often face less entrenched organisational resistance (Acs et al., 2021). Start-ups and scale-ups lead digitalisation among European SMEs by leveraging their more flexible structures, innovation capacity, and market advantages.
— The level of internationalisation. SMEs engaged internationally tend to be more innovative (Jabar et al., 2016; Daszkiewicz, 2019), and as a result, are more likely to adopt AI technologies.
— Firm size. Companies that adopt advanced technologies generally employ more workers than their competitors in the same industry. These firms were already larger and growing more quickly before the rise of artificial intelligence (Acemoglu et al., 2023). Hansen et al. (2024) emphasise that AI adoption is more of a process of maturity, usually associated with company size.
— Types of innovation. AI technology serves more specialised objectives in manufacturing rather than in service sectors, where AI is more extensively integrated into the firm.

However, discussions about AI often focus on technology-driven companies, usually overlooking small and medium-sized businesses. Historically, SMEs have been less enthusiastic about adopting new technologies (Nunn, 2018) and have concerns about change (Holl & Rama, 2024), particularly with AI. SMEs usually focus on daily operations (Handrito et al., 2023) and often struggle to understand the actual impact of AI on their businesses (Schwaeke et al., 2024). Compared to larger corporations, SMEs face unique challenges (Mathagu, 2024) and often encounter constraints due to limited human and financial resources (Dörr et al., 2023).

According to the report "How do SMEs in CEE find their way in the world of AI?" (AI Chamber, 2025), companies that delay AI implementation most often cite a lack of knowledge (39%) and the absence of a clear strategy (21%) (Figure 1). A shortage of experts is also a common issue, highlighting how difficult it is to assemble a team capable of managing this technology today. Almost 30% of companies still believe they do not need AI. Companies also worry about legal issues (12%) and data security (15%), indicating that, for many organisations, AI remains a risky space not yet fully regulated, which breeds caution.

Research based on data from various countries identifies key barriers, including concerns about limited data access, insufficient skills, internal resistance, organisational culture, legal issues, and a lack of financial resources (Table 1).

Figure 1. Why do companies in CEE countries delay implementing AI?

Source: AI Chamber, 2025, "How do SMEs in CEE find their way in the world of AI?", Warsaw.

Table 1. The main barriers and challenges to the adoption of AI technologies

Research	Country	What is holding back the adoption of AI
Lorica & Nathan, 2019	US	1. lack of data, 2. lack of skilled people, 3. company culture.
Cubric, 2020	Worldwide	1. data availability, 2. increased dependence on non-humans, 3. concerns about job security, safety, trust.
Schönberger, 2023	Germany	1. lack of expertise and experience in dealing with AI, 2. difficulties in integrating AI with existing systems, 3. concerns about data privacy and data security.
Mathagu, 2024	UK	1. regulations, 2. perceived relative advantage, 3. management support.
Schwaeke et al., 2024	Worldwide	1. compatibility, 2. culture, 3. resources.
Ionascu, 2025	EU-27	1. lack of expertise, 2. weak regulations, 3. data privacy.

Source: own compilation.

3. Methodology

AI adoption among small and medium-sized enterprises in the European Union (EU) remains highly uneven. Some EU member states have quickly implemented AI solutions, while others are still behind (Figure 2). Given the varying levels of AI adoption among EU member states (Ionascu, 2025), a comparative analysis[2] will be conducted. International comparative research highlights the importance of carefully choosing countries. The main criterion should be the purpose of the comparison and its substantive justification (Kokocińska, 2012). This paper aims to identify the barriers and challenges to AI adoption in the SME sector in three countries at different levels of AI implementation. The purpose is to provide guidance to entrepreneurs and policymakers across the EU. Several methods for conducting international comparative studies can be identified. According to some authors, a study aligns most closely with a scientific model when it compares societies that are similar in many ways but differ in one specific aspect (Cheng, 1984; Balcerowicz & Rzońca, 2011). Poland, Germany and Denmark share a foundation of EU integration and democratic governance. The economies are export-oriented, and the SME sectors are strong. They represent different stages along the same European development path. The countries differ in levels of AI integration: Poland, with some of the lowest levels of AI adoption; Germany, positioned centrally within the European Union and not considered a pioneer in AI (Ulrich & Frank, 2021); and Denmark, which leads the EU in AI adoption among SMEs.

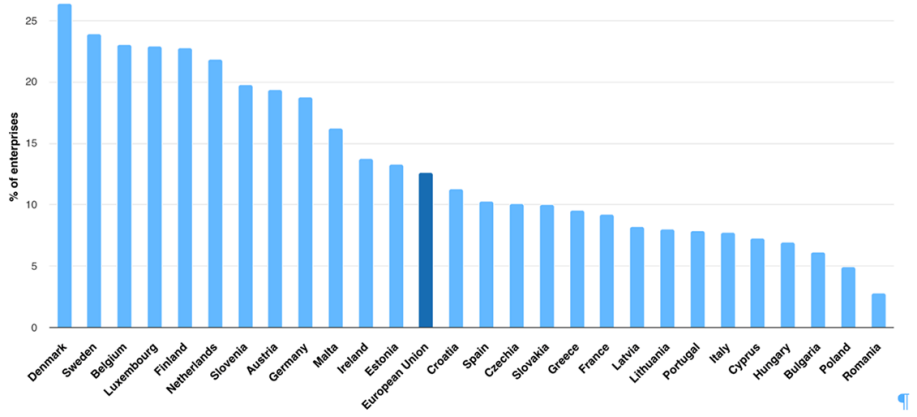

Figure 2. Small and medium-sized enterprises using artificial intelligence[3] in 2024 by country
Source: European Commission, 2025, Digital Economy and Society Index, Brussels.

[2] Although a comparative analysis involves a higher level of risk, this approach allows for more meaningful conclusions than those gained from a single national perspective. In fact, comparative research enables accurate diagnoses and the development of appropriate recommendations for economic policy (Dominiak, 2005).

[3] The artificial intelligence indicator is related to enterprises using any AI technology (European Commission, 2024, Digital Economy and Society Index).

The extent of AI technology implementation may be indicative of the degree of digitalisation (Figure 3). Cubric (2020) emphasised that this represents a crucial determinant, and that insufficient levels of digitalisation within SMEs hinder the adoption of artificial intelligence solutions (Bettoni et al., 2021).

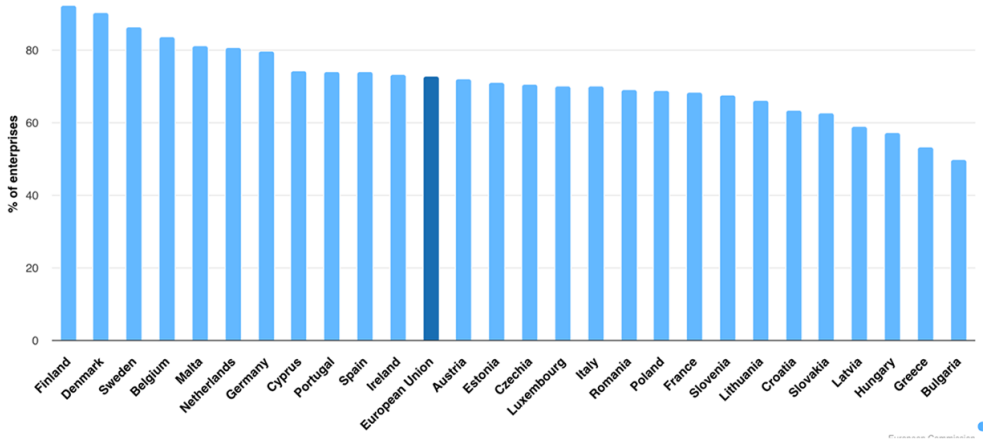

Figure 3. SMEs with at least a basic level of digital intensity[4] in 2024

Source: European Commission, 2025, Digital Economy and Society Index, Brussels.

Notably, in 2024, only 4.9% of Poland's small and medium-sized enterprises used artificial intelligence technologies (compared to an average of 12.6% across the EU-27), and the Digital Intensity Index is 68.9% (compared to the EU-27 average of 72.9%). In Germany, where the Digital Intensity Index is 79.9%, 18.8% of companies use AI. Denmark has 26.4% of SMEs using AI technology, and the Digital Intensity Index among SMEs is 90.5% (Table 2). As a result, in 2024, Poland ranks as the second-least favourable among European Union member states; Germany is in the middle at ninth; and Denmark holds the top spot. These findings indicate that Poland has a negative overall trend in the adoption of digital technologies, particu-

[4] The basic level of digital intensity is based on counting how many out of 12 selected technologies are present: Enterprises where more than 50% of the persons employed have access to the internet for business purposes; The maximum contracted download speed of the fastest fixed internet connection is at least 30 Mb/s; Enterprises with ecommerce sales of at least 1% turnover; Enterprises where web sales are more than 1% of the total turnover and B2C web sales more than 10% of the web sales; Enterprises have document(s) on measures, practices or procedures on ICT security; Enterprises make persons employed aware of their obligations in ICT security related issues; Use at least 3 ICT security measures; Enterprise provided training to their personnel to develop their ICT skills; Employ ICT specialists; Use any AI technology; Provide to the persons employed remote access to the enterprise's e-mail system, documents or applications; Enterprises, which conducted remote meetings via the internet (European Commission, 2024, Digital Economy and Society Index).

larly AI, across SMEs. The German economy shows a positive trend in integrating digital technologies into small and medium-sized enterprises, particularly regarding AI. Denmark, with the highest level of AI adoption, can be considered a leader. Recognising differences between countries is crucial to developing policies that promote the fair adoption of AI across all EU member states. It is essential to examine the barriers and challenges that Polish, German and Danish SMEs face when implementing AI technologies.

Table 2. Integration of digital technology and artificial intelligence in SMEs in Poland, Germany and Denmark compared to the EU-27 average in 2024

Status level	Metrics	POL	GER	DEN	EU-27
Most advanced technologies	SMEs exploiting artificial intelligence	4.9	18.8	26.4	12.6
Digital Intensity Index	SMEs with at least a basic level of digital intensity	68.9	79.9	90.5	72.9

Source: Own studies based on the European Commission, 2025, Digital Economy and Society Index, Brussels.

According to the Central Statistical Office (2024), in Poland in 2024, 94.1% of companies did not utilise artificial intelligence, while 3.2% were not using such solutions but were considering their implementation. The most frequently cited reasons for not adopting AI technology are a lack of human resources and knowledge regarding AI usage (1.9%), followed by the high costs associated with implementing AI technology (1.7%). The least frequently mentioned reason is ethical concerns (0.9%) (Figure 4).

According to the report "AI in Polish Enterprises" (2025) by the Polish Economic Institute, AI in Poland is most often used by microenterprises and large companies. Between 6% and 16% of companies in Poland use AI solutions (depending on the research method). Meanwhile, 77% of entrepreneurs who are not currently using AI have no plans to adopt it unless it becomes necessary. Firms that adopt AI clearly stand out from the rest of the market; they have implemented more digital tools, maintain stronger links with international supply chains, and are more optimistic about the future. Companies using artificial intelligence are 2.5 times more likely to serve foreign customers and more than twice as likely to work with suppliers outside Poland compared to those that have not yet adopted AI solutions (PEI, 2025). This aligns with previous research indicating that international companies tend to be more innovative and willing to embrace AI (Segarra-Blasco et al., 2025). Notably, the Polish Economic Institute (2025) study also indicates that AI initiatives in companies often come from the bottom up, started by employees rather than as part of a formal corporate strategy. This suggests that the actual use of AI tools may

be higher than official data shows. The increasing investment in artificial intelligence technology indicates a positive trend that could lead to further growth of the SME sector (Polish Agency for Enterprise Development, 2025).

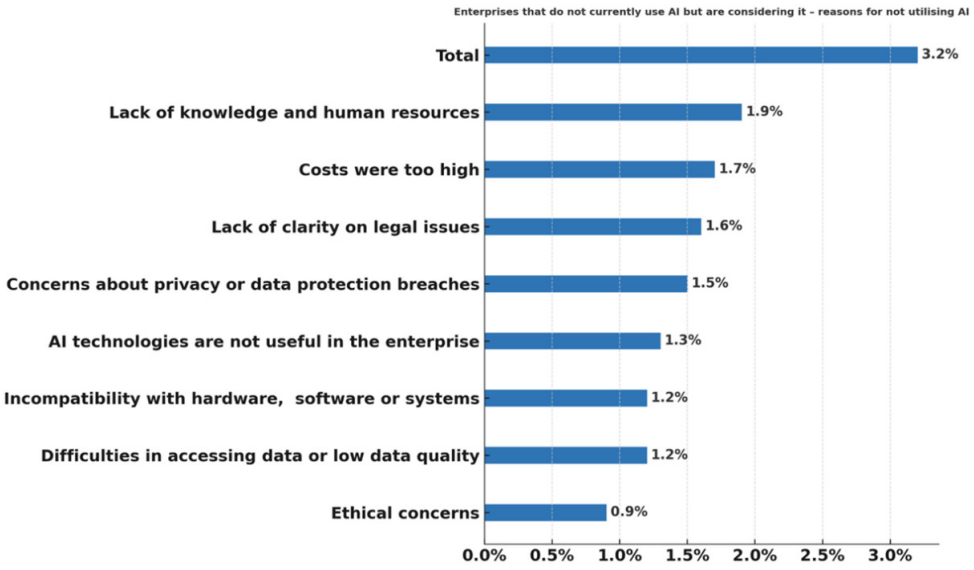

Figure 4. Enterprises that do not currently use artificial intelligence technologies but are considering their implementation vary depending on their reasons for not utilising them

Source: Central Statistical Office, 2024, Information Society in Poland in 2024.

Results from the survey conducted in Germany (Schőnberger, 2023) show that 48% of SMEs cite a lack of knowledge and experience in adopting AI as their primary challenge. German SMEs have not yet fully understood the importance and potential of AI technologies (Ulrich & Frank, 2021). 41% of companies are worried about data privacy and security. Implementing and maintaining AI technologies is considered a significant challenge by 38% of firms due to high costs. 34% of organisations report difficulties in integrating artificial intelligence into their existing systems. Organisations often view the costs of AI solutions as excessively high. 7% of companies are concerned about employment impacts. An additional 7% face difficulties such as insufficient data or a lack of result traceability (Figure 5).

In Denmark, skills remain the biggest bottleneck despite a high DESI ranking; nearly three out of five companies struggle to find the AI talent they need. According to the Iftikhar & Nordbjerg (2021) study, organisational culture and funding barriers are the main challenges. Notably, only 14% of Danish SMEs had adopted any AI by 2023, compared to 51% of large companies. Costs and regulations now outweigh pure technology issues. More than half of innovative companies cite funding

or compliance costs as their primary concerns, rather than algorithmic complexity (Table 3)[5].

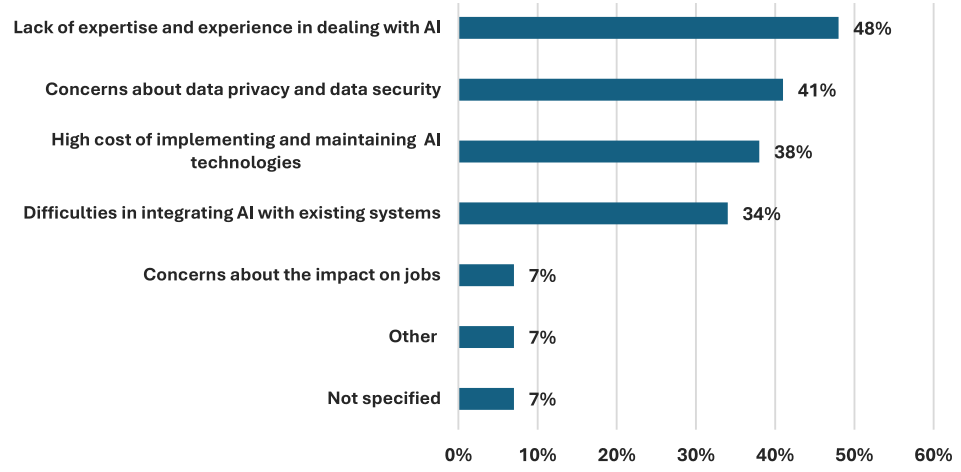

Figure 5. AI implementation challenges in German SMEs

Source: Schönberger, M., 2023, Artificial intelligence for small and medium-sized enterprises: Identifying key applications and challenges*, Journal of Business Management*, 21.

Table 3. The barriers that Danish firms face when adopting artificial-intelligence solutions

Barrier of AI adoption	Research
Skills shortage: 58% of Danish SMEs are struggling to fill vacancies for ICT specialists.	An Implement Consulting Group study commissioned by Google, 2024, *The AI innovation opportunity; How Denmark can scale digital businesses with AI to close the innovation and competitiveness gap.*
In a survey of Danish SMEs, the three obstacles cited most often were: − lack of organisational readiness for change, − shortage of funds for AI projects, − shortage of skilled labour.	Iftikhar, N. & Nordbjerg, F.E., 2021, Adopting *Artificial Intelligence in Danish SMEs: Barriers to Become a Data-Driven Company, Its Solutions and Benefits*, Conference: 2nd International Conference on Innovative Intelligent Industrial Production and Logistics.

[5] The reports selected for Table 3 fulfill criteria such as recency, credibility and relevance to the Danish digitalisation context. Sources were limited to reputable institutions that provide evidence-based and methodologically robust analyses. These reports were chosen because they combine quantitative indicators with qualitative insights on skills shortages, organisational readiness, and financial constraints. Their complementarity enables a comprehensive understanding of the main barriers to AI implementation in Danish SMEs.

continued table 3

Among Danish innovative scale-ups, 61% of firms indicate that the expense of AI tools constitutes a significant barrier, and the costs associated with regulatory compliance are described as "particularly burdensome for small businesses."	An Implement Consulting Group study commissioned by Google, 2024, *The economic opportunity of generative AI in Denmark; Capturing the next wave of benefits from generative AI.*

Source: own compilation.

4. Recommendations

Among EU member states, some countries are quickly adopting AI solutions, while others lag. 2023 Eurostat-DESI data show that only 2.9% of Polish SMEs used AI, compared to 10.8% in Germany and 14.1% in Denmark, placing Poland second-to-last and Denmark first in the EU-27 ranking. This gap is closely linked to each country's Digital Intensity Index (50%, 61% and 75%, respectively), indicating that the overall level of digitalisation and limited digital infrastructure in the economy hinder the deployment of AI solutions in the SME sector.

Across studies and cross-country evidence, internal capabilities such as digital skills, data quality, organisational culture, and financial resources are the strongest predictors of AI adoption. Environmental support is helpful only when institutions are mature.

The barrier profile remains the same, but its strength varies. Barriers usually cluster around issues like data availability and quality, skills gaps, costs, integration with legacy systems, privacy, and cultural resistance. The significance of these barriers differs: in Poland, knowledge gaps and costs are the main concerns; in Germany, data security and lack of expertise in system integration are more significant; and in Denmark, skills and funding are the biggest challenges.

Countries with low AI adoption and limited digitalisation, like Poland, should prioritise strengthening their digital transformation foundations. Key areas include investing in digital infrastructure, expanding industrial networks, and increasing enterprise access to cloud and high-performance computing through national programmes. A significant challenge in these nations is the lack of AI skills and expertise among workers. Governments should launch initiatives offering free or subsidised courses to develop digital and specialised AI skills for employees and job seekers. Moreover, incorporating AI-focused modules into university curricula is vital. Many companies in countries with low AI adoption are unaware of the benefits of AI (Central Statistical Office, 2024), while others hesitate because they perceive it as too complex. To promote AI adoption, it is essential to actively raise awareness of its benefits and address concerns regarding its complexity. Running informational campaigns and pilot projects in key sectors, such as industry or public services, can effectively demonstrate AI's positive impact. Another point is that organisations of-

ten perceive the costs associated with artificial intelligence solutions as excessively high. While this perception may be valid in many cases, it is essential to compare these costs with the potential benefits (Bettoni et al., 2021).

Germany is above the EU average but still far behind Nordic leaders. There is a need to close the expertise gap – the first and most crucial obstacle in German research (Schönberger, 2023), by building expertise and experience in handling AI. However, German companies can bridge this knowledge gap by engaging external experts and utilising vendor support (Aarstad & Saidl, 2019). Additionally, while replicating the AI business models of tech giants may be challenging, smaller businesses can leverage AI as a unique differentiator in their competitive markets. Secondly, AI adoption is limited by data availability and quality; one solution could be making sector data spaces plug-and-play for SMEs.

Countries with high AI adoption face advanced user problems. In Denmark, there remains a shortage of highly specialised skills in key AI areas. The ongoing development of advanced AI expertise and the attraction of global talent are essential. Maintaining a steady supply of skilled professionals to foster innovation can be achieved by funding advanced AI degree programmes at the national level and promoting industry-academic partnerships to enhance high-level skills. Regarding costs, establishing a targeted financial incentive system, such as grants or tax credits, is crucial for encouraging AI adoption among SMEs (Ionascu, 2025).

5. Limitations and Further Research

This study has certain limitations related to data scope and methodological design:

1. The analysis relies mainly on secondary data sources, including statistical indicators from the European Commission and national institutions, as well as reports and surveys. Although these datasets are reliable, they may not fully capture the dynamic and diverse nature of AI adoption within the SME sector.
2. The reliance on aggregated country-level data also limits the ability to assess firm-level variations, such as significant differences across sectors, industries, or organisational maturity levels.
3. The study focuses on three European countries – Poland, Germany and Denmark – that represent different levels of digitalisation. Moreover, the rapid evolution of AI technologies and digital policies means that the results capture only a snapshot of an ongoing transformation.

Future research should therefore employ firm-level empirical studies using both quantitative and qualitative methods to better understand the relationship between AI adoption, internal capabilities, and external factors. It would also provide the opportunity to distinguish different levels of AI advancements. Expanding the geographical scope to include more European countries and sectors or industries would

improve comparative insights. Longitudinal analyses across EU regions would help capture the evolving effects of AI policies, investments, and digital skills development. Additionally, future studies could explore the interaction between institutional factors and innovation diffusion theories to evaluate how regulatory maturity, data ecosystems, and cultural factors collectively influence AI adoption patterns across the SME landscape.

6. Conclusion

The study explored the factors and obstacles of AI adoption among SMEs in Poland, Germany and Denmark. Despite varying levels of digital maturity, internal capabilities such as digital skills, data quality, human capital, organisational culture, and financial resources remain the strongest predictors of AI adoption across studies and countries. Institutional support and regulatory frameworks are beneficial only when institutions are well-developed. Overall, the study improves understanding of how organisational and institutional factors influence the AI transformation of European SMEs.

The evidence confirms that SME AI programmes need to be tailored to each country's stage of adoption. The article consolidates dispersed EU evidence into an accessible benchmark, linking adoption gaps with barrier profiles, and offers country-specific recommendations for policymakers and business leaders to accelerate SME AI adoption and boost competitiveness.

References

1. Aarstad, A. & Saidl, M. (2019). *Barriers to adopting AI technology in SMEs,* Master's Thesis, Copenhagen Business School, Copenhagen.
2. Acemoglu, D., Anderson, G., Beede, D., Buffington, C., Childress, E., Dinlersoz, E., Foster, L., Goldschlag, N., Haltiwanger, J., Kroff, Z., Restrepo, P., & Zolas, N. (2023). Advanced technology adoption: Selection or causal effects? *AEA Papers and Proceedings,* 113, 210–214. American Economic Association. DOI: 10.1257/pandp.20231037.
3. Acs, Z.J., Song, A., Szerb, L., Audretsch, D.B., & Komlosi, E. (2021). The evolution of the global digital platform economy: 1971–2021. *Small Business Economics, 57*(4), 1629–1659. DOI: 10.1007/s11187-021-00561-x.
4. AI Chamber, 2025, How do SMEs in CEE find their way in the world of AI, Warsaw.
5. Albats, E., Alexander, A.T., Cunningham, J.A. (2022). Traditional, virtual, and digital intermediaries in university-industry collaboration: exploring institutional logics and bounded rationality, *Technological Forecasting and Social Change*, 177, DOI: 10.1016/j.techfore.2022.121470.
6. An Implement consulting Group study commissioned by Google, 2024, *The AI innovation opportunity, How Denmark can scale digital businesses with AI to close the innovation and competitiveness gap.*

7. An Implement consulting Group study commissioned by Google, 2024, *The economic opportunity of AI in Denmark, Capturing the next wave of benefits from generative AI.*
8. Ardito, L., Filier, R., Raguseo, E. & Vitari, C. (2025). Artificial intelligence adoption and revenue growth in European SMEs: synergies with IoT and big data analytics, *Internet Research*, *35(4), pp. 1508–1534.* DOI: 10.1108/INTR-02-2024-0195.
9. Arroyabe, M., F., Arranz, C.F.A., Fernandez De Arroyabe, I., Fernandez de Arroyabe, J.C., (2024), Analyzing AI adoption in European SMEs: A study of digital capabilities, innovation, and external environment. *Technology in Society,* 79, DOI: /10.1016/j.techsoc.2024.102733.
10. Awa, H.O., Ukoha, O., & Igwe, S.R. (2017). Revisiting technology-organization-environment (TOE) theory for enriched applicability. *The Bottom Line,* 30(01), 2–22. DOI: 10.1108/BL-12-2016-0044.
11. Bag, S., Pretorius, J.H.C., Gupta, S., Dwivedi, Y.K. (2021). Role of institutional pressures and resources in the adoption of big data analytics powered artificial intelligence, sustainable manufacturing practices and circular economy capabilities. *Technology Forecasting and Social Change,* 163, DOI: 10.1016/j.techfore.2020.120420.
12. Balcerowicz, L. & Rzońca, A. (2011). *Zagadki wzrostu gospodarczego, Siły napędowe i kryzysy – analiza porównawcza*, C.H. Beck, Warsaw.
13. Bettoni, A., Matteri, D., Montini, E., Gładysz, B. & Carpanzano, E. (2021). An AI adoption model for SMEs: A conceptual framework, *IFAC-PapersOnLine,* 54(1), 702–708, DOI: 10.1016/j.ifacol.2021.08.082.
14. Brodny, J. & Tutak, M. (2022). Digitalization of Small and Medium-Sized Enterprises and Economic Growth: Evidence for the EU-27 Countries. *Journal of Open Innovation: Technology, Market, and Complexity,* 8(2), 67, DOI: 10.3390/joitmc8020067.
15. Chen, W. & Filieri, R. (2024). Institutional forces, leapfrogging effects, and innovation status: Evidence from the adoption of a continuously evolving technology in small organizations. *Technological Forecasting and Social Change*, 206, DOI: 10.1016/j.techfore.2024.123529.
16. Cheng, J.C.L. (1984). The Role of Cross-National Research in Organizational Inquiry: A Review and Proposal, Academy of Management Proceedings [in:] Dominiak, P. (2005). *Sektor MSP we współczesnej gospodarce*, Polish Scientific Publishers PWN, Warsaw.
17. Cubric, M. (2020). Drivers, barriers and social considerations for AI adoption in business and management: A tertiary study, *Technology in Society*, 62, DOI: 10.1016/j.techsoc.2020.101257.
18. Central Statistical Office (2024). *Information Society in Poland in 2024,* available at: https://stat.gov.pl/obszary-tematyczne/nauka-i-technika-spoleczenstwo-informacyjne/spoleczenstwo-informacyjne/spoleczenstwo-informacyjne-w-polsce-w-2024-roku,2,14.html (accessed 31 October 2024).
19. Daszkiewicz, N. (Ed.), (2019). *The Internationalization of High-Tech Firms: Patterns, Innovation, and Research and Development*, Newcastle upon Tyne: Cambridge Scholars Publishing.
20. Dominiak, P. (2005). *Sektor MSP we współczesnej gospodarce*, Polish Scientific Publishers PWN, Warsaw.
21. Dörr, L., Fliege, K., Lehmann, C., Kanbach, D. K., & Kraus, S. (2023). A taxonomy on influencing factors towards digital transformation in SMEs. *Journal of Small Business Strategy*, 33(1), 53–69. DOI: 10.53703/001c.66283.

22. El-Haddadeh, R. (2020). Digital innovation dynamics influence on organisational adoption: The case of cloud computing services. *Information Systems Frontiers*, 22(4), 985–999. DOI: 10.1007/s10796-019-09912-2.
23. European Commission (2024a). *Digital Economy and Society Index (DESI) 2024*. DESI indicators available at: https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts/desi-indicators?period=desi_2024&indicator=desi_ai&breakdown=ent_sm_xfin&unit=pc_ent&country=AT,BE,BG,HR,CY,CZ,DK,EE,EU,FI,FR,DE,EL,HU,IE,IT,LV,LT,LU,MT,NL,PL,PT,RO,SK,SI,ES,SE (accessed 31 October 2025).
24. European Commission (2024b). *SME Performance Review, Annual Report on European SMEs 2023/2024* available at: https://single-market-economy.ec.europa.eu/smes/sme-strategy-and-sme-friendly-business-conditions/sme-performance-review_en (accessed 26 January 2025).
25. European Commission (2024c). *SME Performance Review, EU-27 SME Fact Sheet 2024* available at https://ec.europa.eu/docsroom/documents/61039 (accessed 26 January 2025).
26. Habibi, F. & Zabardast. M.A. (2020). Digitalization, education, and economic growth: A comparative analysis of Middle East and OECD countries, *Technology in Society*, 63 (101370), DOI: 10.1016/j.techsoc.2020.101370.
27. Hajoary, P.K., Jennifer, D.S., & Pathak, M. (2024). Digital technology adoption in circular startups: An integrated framework. *Business Strategy & Development, 7*(3), DOI: 10.1002/bsd2.
28. Handrito, R.P., Slabbinck, H. & Vanderstraeten, J. (2023). Stuck in short-term, daily operations, or not? Unraveling SME's long-term orientation. *Small Business Economics*, 61, 1723–1745, DOI: 10.1007/s11187-023-00748-4.
29. Hansen, E. & Bøgh, S. (2021). Artificial intelligence and internet of things in small and medium-sized enterprises: A survey. *Journal of Manufacturing Systems.* 58(Part B). DOI: 10.1016/j.jmsy.2020.08.009.
30. Hansen, H.F., Lillesund, E., Mikalef, P. & Altwaijry, N. (2024). Understanding Artificial Intelligence Diffusion through an AI Capability Maturity Model. I*nformation System Frontiers*, 26, 2147–2163, DOI: 10.1007/s10796-024-10528-4.
31. Hofer, Ch., Jin, H., Swanson, R.D., Waller, M.A. & Williams, B.D. (2012). The Impact of Key Retail Accounts on Supplier Performance: A Collaborative Perspective of Resource Dependency Theory, *Journal of Retailing*, 88(3), 412–420. DOI: 10.1016/j.jretai.2011.12.003.
32. Holl, A. & Rama, R. (2024). SME digital transformation and the COVID-19 pandemic: a case study of a hard-hit metropolitan area, *Science and Public Policy*, 51(6), 1212–1226, DOI: 10.1093/scipol/scae023.
33. Holmström, J. (2022). From AI to digital transformation: The AI readiness framework. *Business Horizons, 65*(3), DOI: 10.1016/j.bushor.2021.03.006.
34. Hossain, M.A., & Quaddus, M. (2012). *Expectation–confirmation theory in information system research: A review and analysis* (Vol. 28). Springer. DOI: 10.1007/978-1-4419-6108-2_21.
35. Husillos, M.H. (2024) Robotics, AI and Job Displacement: Fears of Job Loss vs Upskilling and Reskilling—The European Financial Review. https://www.europeanfinancialre-

view.com/robotics-ai-and-job-displacement-fears-of-job-loss-vs-upskilling-and-reskilling/ (accessed 15 July 2025).
36. Iftikhar, N. & Nordbjerg, F.E., 2021, Adopting *Artificial Intelligence in Danish SMEs: Barriers to Become a Data-Driven Company, Its Solutions and Benefits*, Conference: 2nd International Conference on Innovative Intelligent Industrial Production and Logistics., DOI: 10.5220/0010691800003062.
37. Ionascu, C.M. (2025). Artificial Intelligence Adoption in the European Union: A Data-Driven Cluster Analysis (2021–2024), *Economies*, *13*(5), 145, DOI: 10.3390/economies13050145.
38. Jabar, F.H.A., Tajuddin, N. and Paino, H. (2016). Internationalization of Small and Medium Enterprises. In: Mohd Sidek, N., Ali, S., Ismail, M. (eds) *Proceedings of the ASEAN Entrepreneurship Conference 2014.* Springer, Singapore. DOI: 10.1007/978-981-10-0036-2_14.
39. Jiao, H., Yang, J. and Ciu, Y. (2022). Institutional pressure and open innovation: the moderating effect of digital knowledge and experience-based knowledge. Journal of Knowledge Management 2, 26(10). DOI: 10.1108/JKM-01-2021-0046.
40. Kandeel, M.E., Saleh B.A., Elrefae, G., Elsantil, Y.G. (2024). Empowering Small and Medium Enterprises (SMEs) through Artificial Intelligence. *2024 Fifth International Conference on Intelligent Data Science Technologies and Applications (IDSTA)*, DOI: 10.1109/IDSTA62194.2024.10746984.
41. Kokocińska, M. (2012). *Małe i średnie przedsiębiorstwa w gospodarkach europejskich*, Publishing House of the Poznań University of Economics, Poznań.
42. Lorica, B., Nathan, P. (2019). *AI Adoption in the Enterprise.* O'Reilly Media, Inc.
43. Mathagu, S.W., (2024). Artificial Intelligence in Small and Medium Enterprises – An Empirical Analysis of Critical Factors. *Premier Journal of Science,* 1, DOI: 10.70389/PJS.100009.
44. Nguyen, T.H., Le, X.C., & Vu, T.H.L. (2022). An extended technology-organization-environment (TOE) framework for online retailing utilization in digital transformation: Empirical evidence from Vietnam. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(4), 200. DOI: 10.3390/joitmc8040200.
45. Nunn, J. (2018). *How SMEs can catch the AI wave?,* available at: https://www.forbes.com/sites/forbestechcouncil/2018/08/07/how-smes-can-catch-the-ai-wave/ (accessed 19 January 2025).
46. Oldemeyer, L., Jede, A., Teuteberg, F. (2024. Investigation of artificial intelligence in SMEs: a systematic review of the state of the art and the main implementation challenges, *Management Review Quarterly*, 75 (2), 1185–1227, DOI: 10.1007/s11301-024-00405-4.
47. Peretz-Andersson, E., Tabares, S., Mikalef, P. & Parida, V. (2024). Artificial intelligence implementation in manufacturing SMEs: A resource orchestration approach. International Journal of Information Management, 77, DOI: 10.1016/j.ijinfomgt.2024.102781.
48. Polish Agency for Enterprise Development. (2025). Report on the condition of the SME sector 2024, available at: https://www.parp.gov.pl/component/publications/publication/raport-o-stanie-sektora-malych-i-srednich-przedsiebiorstw-w-polsce-2025 (accessed 31 October 2025).
49. Polish Economic Institute. (2025). AI in Polish Enterprises, available at: https://pie.net.pl/z-ai-korzysta-mniej-niz-co-szosta-firma-w-polsce-a-pozostale-nie-planuja-jej-wdrazac/ (accessed: 31 October 2025).

50. Sánchez, E., Calderón, R., & Herrera, F. (2025). Artificial Intelligence Adoption in SMEs: Survey Based on TOE–DOI Framework, Primary Methodology and Challenges. *Applied Sciences*, *15*(12), DOI: 10.3390/app15126465.
51. Schoeman, F. & Seymour, L. (2022). Understanding the Low Adoption of AI in South African Medium-Sized Organisations*, EPiC Series in Computing,* 85, 257-269. DOI: 10.29007/c4rr.
52. Schönberger, M. (2023). Artificial intelligence for small and medium-sized enterprises: Identifying key applications and challenges*, Journal of Business Management,* 21, 89–112. DOI: 10.32025/JBM23004.
53. Schwaeke, J., Peters, A., Kanbach, D.K., Kraus, S., & Jones, P. (2024). The new normal: the status quo of AI adoption in SMEs. *Journal of Small Business Management*, 63(3), 1297–1331. DOI: 10.1080/00472778.2024.2379999.
54. Segarra-Blasco, A., Tomàs-Porres, J. & Teruel, M. (2025). AI, robots and innovation in European SMEs. *Small Bus Economics,* 65, 719–745. DOI: 10.1007/s11187-025-01017-2.
55. Singh, S. (2024). *Small Businesses and AI: Accelerating Innovation and Inclusion*, available at: https://hbr.org/sponsored/2024/10/small-businesses-and-ai-accelerating-innovation-and-inclusion (accessed 19 January 2025).
56. Ulrich, P. & Frank, V. (2021). Relevance and adoption of AI technologies in German SMEs – results from survey-based research. *Procedia Computer Science*, 192, 2152–2159, DOI: 10.1016/j.procs.2021.08.228