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Article

Entrepreneurial Orientation in the Age of Artificial Intelligence: A Study of SMEs in the Visegrad Chemical Sector

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Abstract

This study explores the relationships among Entrepreneurial Orientation (EO), artificial intelligence (AI) adoption, and internationalisation strategies, and their influence on the performance of small and medium-sized enterprises (SMEs). Focusing on the Visegrad chemical sector, the research employs a novel quantitative tool to measure AI adoption across 136 SMEs. The findings reveal a significant relationship between EO and effective AI integration, underscoring EO's central role in enhancing technological competitiveness and facilitating global market expansion. The study also sheds light on the EO–performance connection within this specific regional and industrial context, offering broader insights for transition economies and high-tech sectors. By addressing gaps in the existing literature, it contributes to the growing discourse on technology-driven entrepreneurship. The practical and policy implications stress the importance of strengthening EO and technological capabilities to support sustain growth and improve organisational performance amid rapid digital transformation and global economic change.

Keywords: artificial intelligence adoption; entrepreneurial orientation; internationalisation; SME performance; Visegrad chemical industry
JEL: F23, L25, L26, O33

1. Introduction

In a rapidly evolving business landscape, marked by technological advancements, entrepreneurial firms face the challenge of adapting and thriving (Bartlett and Mroczkowski, 2019). This study ventures into the relatively uncharted territory of the Visegrad chemical industry, examining the interplay between entrepreneurial orientation (EO), artificial intelligence (AI) adoption, internationalisation, and small and medium-sized enterprises (SME) performance. While the correlation between EO, SME performance, and internationalisation is well-documented, this paper extends the inquiry into new geographical and industrial contexts.

The Visegrad countries—the Czech Republic, Hungary, Poland, and Slovakia—provide a strategic focus for studying the entrepreneurial orientation (EO) of SMEs. Representing a unique economic bloc within Central Europe, these nations share a common history of transitioning from centrally planned economies to market-driven systems in the early 1990s. This shift has fostered an entrepreneurial environment that blends the dynamism of emerging markets with the structure and stability of the European Union's (EU27) economic framework (Dziembala, 2018). SMEs, forming the majority of businesses and employing over 65% of the workforce across the EU27 (EU27 - SME Fact Sheet 2021), are particularly significant in the Visegrad group. Within this context, the Visegrad region provides a distinct setting to explore how EO influences SMEs as they confront the combined challenges of rapid economic development and the pressures of globalisation.

The chemical sector within these Visegrad countries further underscores the relevance of this study due to its critical role in both regional and European contexts. This industry, which includes chemicals, rubber and plastics, and pharmaceuticals, is a substantial component of the EU's manufacturing base, employing approximately 3.4 million people, or 12.3% of the EU27's manufacturing workforce (Cefic, 2024). Characterised by high technological innovation, strict regulatory frameworks, and intense global competition, the chemical sector presents an ideal context for studying AI adoption. The constant pressure to innovate and enhance efficiency highlights the importance of EO for SMEs, particularly as they navigate the complexities of operating in one of Europe's most influential industries.

A particular focus is placed on the proactive adoption of AI by entrepreneurial SMEs, utilising a novel measurement tool. This research not only bridges a crucial gap in existing literature but also offers a comprehensive view of the impact of entrepreneurial strategies on technology adoption and international growth.

This study employs the Dynamic Capabilities Theory as the primary framework to understand how EO drives AI adoption and internationalization in small and medium-sized enterprises. Dynamic Capabilities Theory posits that firms with strong dynamic capabilities can adapt, integrate, and reconfigure internal and external competencies to ad-

dress rapidly changing environments, aligning well with the proactive, innovative, and risk-taking dimensions of EO (Teece et al, 1997).

Additionally, the Resource-Based View (RBV) and the Technology Acceptance Model (TAM) provide supplementary theoretical perspectives. RBV describes EO as a valuable, rare, and inimitable resource that firms can leverage for competitive advantage (Barney, 1991). Meanwhile, TAM explains how EO influences the perceived usefulness and ease of use of AI technologies, facilitating their adoption (Davis, 1989). By integrating these theories, this study aims to offer a comprehensive understanding of the interplay between EO, AI adoption, and internationalization.

Recent investigations, including studies by Hrubý and Koráb (2018) and Hruby (2021), have pinpointed a significant research gap in understanding the impact of EO within Central European chemical SMEs. EO, a central concept in entrepreneurship studies, has been scrutinized for decades. Yet, the relationship between EO and firm performance, remains somewhat ambiguous, as indicated by Rauch et al (2009) and Wales et al (2021). Existing research, such as Javalgi and Todd (2011), has explored the influence of entrepreneurship on firm internationalization, but a comprehensive understanding in the context of the V4 chemical industry is still lacking. Wales et al (2021) specifically highlights the need for assessing EO in diverse environments and encourages exploration within new sectors like the V4's chemical industry. This study aims to fill these gaps by investigating the potential positive relationships between EO, SME performance, and internationalisation in this unique sector.

Additionally, this study addresses the burgeoning interest in AI, especially in the wake of advancements in technologies like Large Language Models (LLMs) (Arcas, 2022). It examines how entrepreneurially oriented firms are adopting AI, using a novel measurement tool developed in a preceding pilot study. A preliminary survey of scholarly databases such as Scopus and Web of Science reveals a gap in understanding the impact of EO on AI adoption an area ripe for exploration as suggested by Baldegger et al (2020), who note the tendency of entrepreneurially oriented firms to integrate AI into areas like Human Resource management (HRM).

This quantitative study draws on data from 136 SMEs, collected through a comprehensive questionnaire that combines established scales for measuring EO, performance, internationalisation, and newly developed scales for AI adoption. The next chapter lays the theoretical groundwork and presents the research hypotheses. The Methodology and Data chapter details the study's design and execution, including the selection of data collection tools and control variables. The paper culminates in a thorough presentation and discussion of the results, leading to a conclusion that encapsulates the study's key contributions to the field.

2. Theory and Hypotheses

This paper will explore the dynamics between EO and three dependent variables—performance, artificial intelligence (AI) adoption, and internationalisation. While this study empirically tests these relationships within the Visegrad chemical sector, the relationships explored have broader implications for SMEs operating in similarly transitional economies and technology-intensive industries.

Our discourse commences with an in-depth discussion on EO, a concept that has attracted considerable scrutiny within the domain of entrepreneurship studies (Covin and Wales, 2012). Following sections will introduce and rationalise the hypotheses that emerge from this theoretical foundation. The chapter culminates in the unveiling of the research model in Fig. 1, graphically representing the postulated relationships and laying the groundwork for the ensuing methodological scrutiny.

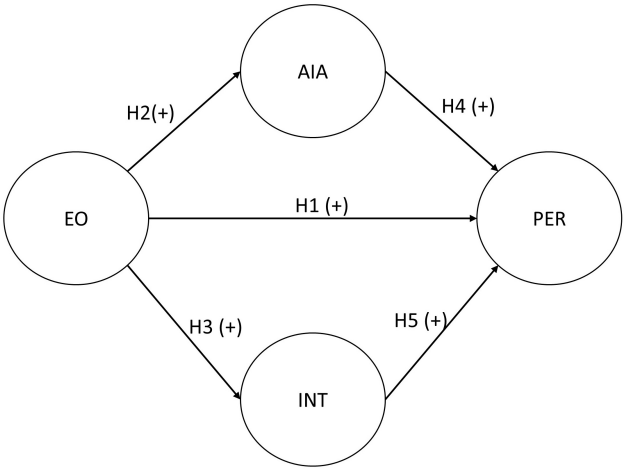

Fig. 1. Research model. EO, entrepreneurial orientation; AIA, artificial intelligence adoption; INT, internationalisation; PER, performance; H, hypothesis.

2.1 Entrepreneurial Orientation: Definitions, Historical Development, and Key Dimensions

Entrepreneurial Orientation (EO) can be defined as a firm's strategic approach to entrepreneurship, encompassing the processes, practices, and decision-making activities that lead to new entry. EO is typically characterised by three key dimensions—innovativeness, risk-taking, and proactiveness (Gupta and Gupta, 2015). EO has been the subject of significant academic debate, particularly regarding its classification as either a behavioural construct, an attitudinal construct, or a combination of both. Anderson et al (2015) propose that EO integrates both entrepreneurial behaviours and managerial attitudes towards risk, suggesting that these dimensions collectively form a higher-order EO construct. They argue that considering EO from both

perspectives addresses potential measurement inaccuracies and provides a more comprehensive understanding of a firm's entrepreneurial stance.

Some researchers including this author focus primarily on EO as a set of behaviours that firms exhibit. This includes innovativeness, proactiveness, and risk-taking, which are fundamental to entrepreneurial activities. For example, Wolff et al (2015) argue that EO significantly influences SMEs through the implementation of these behaviours.

Others see EO as rooted in leadership attitudes and strategic decision-making. Engelen et al (2015) discuss how transformational leadership behaviours can amplify the effects of EO on firm performance, emphasising the importance of managerial perspectives. A hybrid view integrates both behavioural and attitudinal dimensions, as suggested by Anderson et al (2015), who argue that understanding EO requires considering both firms' strategic actions and leadership orientations.

White et al (2021) suggest that a firm's entrepreneurial approach is shaped by its recognition of emerging opportunities and a propensity to innovate in products and services. Gupta and Wales (2017) describe EO as a measure of how deeply entrepreneurial characteristics are embedded in a firm's operations and decision-making, significantly influencing performance outcomes. Baldegger et al (2021) further elaborate on EO, characterising it as the combination of a firm's processes, activities, policies, and decision-making approaches, which collectively drive entrepreneurial initiatives.

Tracing the origins of EO, Miller (1983) proposed that a truly entrepreneurial firm must simultaneously exhibit innovativeness, proactiveness, and risk-taking. This perspective led to EO being initially conceptualised as a unidimensional construct (Gupta and Wales, 2017). However, Lumpkin and Dess (1996) challenged this notion, arguing for a multidimensional approach by introducing additional dimensions—competitive aggressiveness and autonomy—suggesting that a firm need not express all dimensions simultaneously to be considered entrepreneurial.

Despite this, the majority of scholars, including Gupta and Wales (2017), have continued to study EO as a unidimensional construct. This study also aligns with the dominant unidimensional perspective. Nevertheless, EO research continues to evolve. Lumpkin and Pidduck (2021) propose that EO has transcended its original conceptualisation as a firm-level strategy construct. They advocate for a revised, multidimensional framework that better captures the diverse manifestations of entrepreneurial activity across industries and economies. This updated definition acknowledges the complexity and adaptability of EO, reflecting the evolving landscape of entrepreneurial activities in a globalised business environment.

EO remains a complex construct that has undergone significant evolution, presenting a framework to understand the essence of entrepreneurial behaviour within firms. The following subsections examine each of these dimensions in detail, beginning with Miller's (1983) original trio and incorporating the additional perspectives introduced by Lumpkin and Dess (1996) to offer a comprehensive overview of EO's components.

To further understand the multifaceted nature of EO, it is essential to consider its role as both a strategic resource and a dynamic capability. From the Resource-Based View (RBV), EO is seen as a key resource that provides firms with a competitive edge due to its unique attributes—innovativeness, proactiveness, and risk-taking (Barney, 1991). These attributes make EO difficult for competitors to imitate, thereby sustaining a firm's competitive advantage. Meanwhile, Dynamic Capabilities Theory emphasizes the ability of firms with high EO to continuously reconfigure their resources and competencies to address rapidly changing environments (Teece et al, 1997). This reconfiguration is particularly significant in the context of AI adoption and international expansion, where firms must swiftly adapt to new technologies and market dynamics to remain competitive.

Innovativeness is defined as a firm's inclination towards embracing new ideas, fostering experimentation, and cultivating creative processes that lead to the introduction of novel products, services, or technological advancements, as originally posited by Miller (1983). In a focused investigation within the hotel sector, Hernández-Perlines et al (2020) found innovativeness to be a crucial driver of entrepreneurial orientation, emphasising its fundamental role in crafting entrepreneurial strategies and enhancing outcomes. This underscores the strong positive influence of innovativeness on a firm's entrepreneurial posture. Extending this discourse, Santos et al (2020) introduced a novel perspective, arguing that the impact of entrepreneurial orientation extends beyond firm-level strategies to include individual characteristics and behaviours that are pivotal for entrepreneurial efficacy. Their research broadened the traditional conceptualisation of EO by incorporating personal traits such as passion and perseverance as key components of an individual entrepreneurial orientation scale, thereby enriching our understanding of the multifaceted nature of entrepreneurial dynamism.

Proactiveness, as a crucial dimension of entrepreneurial orientation, was comprehensively defined by Lumpkin and Dess (2001) as the capacity for anticipation, characterised by a forward-looking perspective that enables firms to act pre-emptively in response to future demands, needs, or shifts, thereby capitalising on opportunities. This characteristic goes beyond mere reaction to existing situations, embodying a proactive approach to navigating market dynamics. In the context of contemporary entrepreneurship research, proactiveness is associated with strategic foresight, a drive for innovation, and a readiness to pioneer emerging trends or technologies ahead

of competitors. It encompasses not only the identification of novel opportunities but also a firm commitment to their pursuit. This often requires a departure from conventional methods and venturing into new, unexplored domains, as highlighted by Mühlroth and Grottke (2020), thereby underscoring the transformative potential of proactiveness in shaping entrepreneurial ventures.

Risk-taking is defined by a firm's willingness to undertake bold initiatives, such as entering unexplored markets, allocating substantial resources to projects with uncertain outcomes, and making decisions that diverge from industry norms. This aspect is crucial for spurring innovation and securing a competitive edge within entrepreneurial endeavours, as noted by Miller (1983). Expanding on this concept, McCarthy et al (2018) examine risk-taking's vital role in enhancing innovativeness, particularly for firms operating under volatile and unpredictable conditions, such as those found in Russia. Their study explores risk-taking not only as an inclination but also as a tangible action, revealing that both dimensions contribute meaningfully to a firm's innovative capabilities. This insight presents an intriguing perspective, especially when contrasted with the more predictable environments of developed economies, suggesting that the relationship between risk-taking and innovation may be even more pronounced in high-uncertainty contexts.

Competitive aggressiveness refers to a firm's tendency to confront its competitors head-on, deploying assertive and vigorous tactics in the market to secure a foothold or enhance its standing. This approach is marked by a proactive and bold stance against competition, aiming for dominance through relentless effort, as characterised by Lumpkin and Dess (1996). However, the effectiveness of competitive aggressiveness, particularly in hypercompetitive environments, is nuanced. Andrevski and Ferrier (2019) argue that while aggressive competitive strategies can bolster firm performance, their success is largely dependent on the firm's possession of specialised technological resources and a robust network of alliance partners. This suggests that competitive aggressiveness, as a strategy, delivers the greatest benefit when supported by strategic assets and strong collaborative relationships, indicating its conditional value in the pursuit of market leadership.

Autonomy is fundamentally about the freedom to make decisions and take actions within an organisation, aimed at seizing new opportunities, fostering innovation, and driving growth. This essential element of EO underscores the significance of autonomy in cultivating an entrepreneurial spirit and capabilities within firms, enabling them to respond flexibly and innovatively to market shifts and emerging opportunities, as identified by Lumpkin and Dess (1996). This aspect of EO, particularly when coupled with organisational flexibility and responsiveness, has been shown to enhance firm performance. The evolution of autonomy from an emphasis on solitary independent action to a broader perspective that acknowledges the synergy between internal characteristics and external environments marks a notable development in understanding its role in entrepreneurial success. This expanded view illustrates the multi-layered nature of autonomy as a driver of entrepreneurial achievement, highlighting its integral role in the strategic adaptability that underpins innovation and growth.

2.2 Entrepreneurial Orientation and Firm Performance

The interaction between entrepreneurial orientation (EO) and company performance, particularly in small and medium-sized enterprises (SMEs), is a critical area of study within the field of entrepreneurship (Abbas et al, 2023). This relationship is especially significant in the fiercely competitive chemical sector of the Visegrad region, where the need for dynamic capabilities and innovative strategies is paramount to maintaining competitiveness and fostering growth. In this context, performance extends beyond simple financial indicators to include a broader range of outcomes such as rates of innovation, market share expansion, and the adoption of sustainable practices (Wales et al, 2013).

SMEs, due to their size, often display agility and adaptability, enabling them to respond to market changes and opportunities more swiftly than larger counterparts. The extent to which these SMEs can leverage their EO for enhanced performance remains a significant research focus (Lonial and Carter, 2015). Empirical evidence demonstrates a positive correlation between EO and SME performance, highlighting EO's role in promoting business practices that drive superior outcomes (Atluntas and Donmez, 2010; Hossain and Al Asheq, 2019). A pivotal study by Rauch et al (2009), which analysed 53 samples from 51 studies encompassing 14,259 firms, confirmed the positive impact of EO on firm performance across various contexts, including the competitive chemical industry. This meta-analysis revealed a moderately large correlation, with an r value of 0.242, demonstrating the significant influence of EO on firm success. Rauch et al (2009)'s work, celebrated with the 2015 Grief Research Impact Award, underscores the critical role of EO in enhancing firm performance, particularly in high-technology sectors akin to the chemical industry. These sectors, characterised by continuous innovation and the need for rapid market responsiveness, reflect the challenges and opportunities found in the chemical industry, where EO can significantly contribute to firm growth and success (Moreno and Casillas, 2008).

Recent studies have further refined our understanding of EO, exploring its impact on firm performance in a variety of settings. Wales (2016) emphasised EO's relevance to firm success across industry sectors, including the chemical sector. Additionally, empirical research highlights a consistent positive correlation between EO and both financial and non-financial performance indicators, reinforcing

the notion that EO's strategic dimensions are essential for SME competitiveness and long-term growth (Hughes and Mustafa, 2017).

The following hypothesis is grounded in the Resource-Based View (RBV) of the firm, which suggests that firms' unique resources and capabilities, such as EO, are sources of competitive advantage and superior performance (Kraaijenbrink et al, 2010).

Thus, considering the theoretical and empirical evidence, it is hypothesized that entrepreneurial orientation serves as a critical strategic asset for SMEs. By fostering innovation, a proactive market stance, and risk-taking, EO is anticipated to positively influence the performance of these firms. Therefore, the proposed hypothesis is:

Hypothesis 1: There is a positive relationship between the entrepreneurial orientation and performance of SMEs.

This hypothesis contributes to the ongoing discussion on the strategic importance of EO in boosting the competitiveness and performance of SMEs within this specific industrial and geographical context.

2.3 Entrepreneurial Orientation and Artificial Intelligence Adoption

In the year 2023, the conversation around artificial intelligence (AI) has transcended academic circles, fuelled by breakthroughs in technologies like OpenAI's ChatGPT, as highlighted by Dell'Acqua et al (2023). An initial examination of scholarly repositories such as Scopus and Web of Science reveals a notable scarcity of studies exploring the convergence of AI and Entrepreneurial Orientation (EO), indicating a rich opportunity for further research. AI, as defined by Vrontis et al (2022), showcases quasi-human capabilities in performing intricate tasks, drawing on vast external data sources, including the Internet of Things (IoT) and large databases. It harnesses this information to discern patterns and principles, primarily through machine learning, enabling systems to acquire knowledge and capabilities autonomously, without direct programming (Kaplan and Haenlein, 2019). The advent of innovative technologies has consistently acted as a catalyst for business transformation, with AI being the latest driver of change. Its proficiency in learning, connecting, and adapting positions AI as a pivotal force in reshaping business frameworks and methodologies (Huang and Rust, 2021). For small and medium-sized enterprises (SMEs), the integration of AI opens avenues for redefining business processes, enhancing supply chain efficiency, reducing operational costs, mitigating external shocks, and developing new business models (Vrontis et al, 2022). However, for SMEs, AI also presents a paradox: while it offers substantial advantages such as task automation and advanced data analysis, it also introduces challenges and necessitates significant investment for effective adoption (Giotopoulos et al, 2017).

Research consistently shows that firms with a strong EO possess a superior ability to identify and capitalise on technological innovations, including AI. Studies suggest that EO not only drives opportunity recognition within the technological landscape but also enhances a firm's capacity to navigate the complexities of AI adoption, particularly within SMEs.

For instance, Dubey et al (2020) find that EO significantly influences the adoption of big data analytics (BDA) and AI in manufacturing. They argue that EO supports the exploration and application of BDA-AI capabilities, thereby enhancing operational performance. This implies that SMEs with high EO are more inclined to adopt AI, leveraging it as a strategic tool to strengthen their competitive advantage.

Echoing this sentiment, Baldegger et al (2020) identify a robust linkage between EO and the propensity to adopt AI in human resource management (HRM) processes. Their findings articulate that firms with a strong EO are not only more likely to integrate AI into HRM but also view AI adoption positively, anticipating the creation of new roles alongside the obsolescence of some jobs, thus predicting a balanced impact on overall employment.

Similarly, Cenamor et al (2019) suggest that SMEs with an entrepreneurial mindset are well-positioned to enhance their performance through digital platforms, indicating a natural tendency toward adopting cutting-edge technologies like AI. This inclination is further supported by Fan et al (2021), who demonstrate a direct link between EO and SME performance, with social media adoption serving as a proxy for technological innovation. Together, these findings point to a broader pattern: SMEs characterised by a strong EO are more likely to embrace emerging technologies, including AI.

The Technology Acceptance Model (TAM) offers a useful lens for understanding how EO influences AI adoption. TAM posits that perceived usefulness and ease of use are key determinants of technology adoption (Davis, 1989). Entrepreneurial firms, characterised by innovativeness, proactiveness, and risk-taking, are more likely to perceive AI technologies as beneficial and user-friendly, thus facilitating their adoption.

Given the above, it is plausible to hypothesize that:

Hypothesis 2: There is a positive relationship between the entrepreneurial orientation of SMEs and their likelihood to adopt AI technologies.

While both Hypotheses 1 and 2 involve EO, they examine its relationship with different outcomes. H1 focuses on EO's impact on firm performance, whereas H2 addresses its influence on AI adoption. This distinction highlights the separate dependent variables and theoretical foundations underlying each hypothesis.

2.4 Entrepreneurial Orientation and Internationalisation

There is increasing consensus in research that EO plays a vital role in enabling firms to successfully enter and thrive in global markets. As the economy continues to glob-

alise, understanding EO's nuances becomes key to gaining a competitive edge in international markets. This discussion points to a robust relationship between EO and international performance, referencing foundational research such as Zahra and Garvis (2000) and Wales et al (2019).

Javalgi and Todd (2011) characterise internationalisation as the adjustment process through which a firm tailors its strategy, structure, and resources to various global contexts. This notion integrates trade theory, organisational theory, and international entrepreneurship theory, offering a comprehensive perspective on a company's growth beyond domestic borders. Dörrenbächer (2000) notes that 'internationalisation' carries multiple meanings in the business context, being interpreted both as a process and as a measure of a company's degree of international integration.

Recent studies have shed light on the complex relationship between EO and internationalisation in SMEs, and how this dynamic affects their global operations. Javalgi and Todd (2011) observed a positive correlation between a firm's EO and its level of internationalisation, also noting that firm size and age significantly influence international expansion. Research into traditional manufacturing SMEs by Dominguez and Mayrhofer (2017) underscores the fluctuating nature of international commitment, reinforcing the idea that internationalisation is a flexible and evolving growth strategy. Dai et al (2014) explored how different EO dimensions—innovativeness, proactiveness, and risk-taking—affect a firm's capacity for international expansion. They found that each of these dimensions contributes in nuanced ways to the internationalisation process, suggesting that a balanced EO strategy is essential for successful global engagement. Furthermore, SMEs with a pronounced entrepreneurial orientation are better equipped to improve their international performance through strategic alliances. These partnerships are particularly effective in overcoming the resource constraints that SMEs often face in foreign markets. However, the success of such alliances—whether in research, development, or marketing—depends on their alignment with the firm's core strengths (Brouthers et al, 2015).

Applying Dynamic Capabilities Theory, EO enables SMEs to sense and seize international opportunities by continually adapting their strategies and resources to meet changing market conditions. Firms with strong EO are adept at identifying and capitalising on emerging opportunities in global markets due to their proactive and innovative orientation (Teece et al, 1997). This adaptability allows them to reconfigure their competencies effectively, facilitating international expansion. For example, EO-driven SMEs can swiftly adapt their product offerings, marketing approaches, and operational processes to meet the diverse demands of international customers. Such strategic agility is essential for navigating the complexities of foreign markets, where economic, cultural, and regulatory conditions can differ substantially. Thus, EO not only motivates SMEs to pursue internationalisation but also equips them with the capabilities necessary to sustain and enhance performance across borders.

The interplay between EO and internationalisation in SMEs is multifaceted, with innovation, forward planning, and risk-taking at its core. This orientation transcends economic returns alone, fostering innovation and supporting sustainable development—highlighting EO's broad impact on SMEs' global reach. Wales et al (2019) acknowledge the varied approaches used to examine EO's influence on internationalisation and advocate for further exploration into how EO enhances international performance in specific contexts, such as the Visegrad chemical industry. These studies collectively underline EO's pivotal role in enabling firms to explore and succeed in global markets through innovative action, proactive engagement, and strategic risk-taking. Drawing from the theoretical and empirical foundations outlined, the following hypothesis is proposed:

Hypothesis 3: There is a positive relationship between the entrepreneurial orientation of SMEs and their level of internationalisation.

2.5 Artificial Intelligence Adoption and Performance

In recent years, the backbone of commerce has progressively shifted into the digital domain, creating intricate interconnections between products, services, and operations. This evolution has led a wide range of sectors to embrace digital solutions—spanning information, computing, communication, and connectivity—not only to transform their strategic outlook but also to modernise their operational approaches, capabilities, offerings, and core relationships within broader business ecosystems (Bharadwaj et al, 2013). According to Wales et al (2023), innovations such as artificial intelligence (AI) can free entrepreneurial ventures from routine tasks, allowing them to redirect efforts and resources toward strategic initiatives—such as entering new markets—instead of remaining absorbed in day-to-day operations.

Giuggioli and Pellegrini (2023) have highlighted the evolving research landscape, underscoring AI's pivotal role in entrepreneurship and business performance. SMEs are increasingly adopting AI technologies as a strategic tool to streamline processes. From improving supply chain logistics to reducing operational costs, enhancing customer engagement strategies, and mitigating external shocks, AI enables SMEs to navigate contemporary challenges with greater agility. Vrontis et al (2022) further argue that AI's capacity to support the development of innovative business models can significantly reshape how SMEs operate, establishing new standards for efficiency and adaptability.

Baldegger et al (2020) describe AI as a crucial enabler for creating new value propositions in environments marked by uncertainty. Despite the unpredictable trajectory of AI's full potential, its integration into daily operations is

increasingly seen not just as a strategic advantage but as a necessity for maintaining competitiveness in today's fast-evolving markets.

The discourse on how AI adoption affects SME performance is rapidly expanding, with mounting evidence pointing to tangible benefits such as increased sales and job creation (Alekseeva et al, 2020; Babina et al, 2024). Shepherd and Majchrzak (2022) go further, suggesting that when AI is combined with entrepreneurial orientation, it becomes a powerful engine of opportunity, unlocking substantial gains in operational performance. Based on these insights, the following hypothesis is proposed:

Hypothesis 4: There is a positive relationship between the adoption of artificial intelligence by SMEs and their performance.

This hypothesis reflects the author's belief in AI's transformative potential as a catalyst for improved business operations and long-term success.

2.6 Internationalisation and Performance

The landmark study by Lu and Beamish (2001) suggests that engaging in international ventures strengthens a firm's competitive position by exposing it to diverse market conditions and operational challenges. This exposure enhances adaptability, stimulates innovation, and contributes to improved overall performance.

Research consistently indicates a positive link between the degree of SME internationalisation and performance across sectors. Studies show that internationally active SMEs often outperform their domestically focused counterparts in areas such as innovation, revenue growth, and market expansion (Zahra et al, 2000). This superior performance stems from the knowledge and capabilities acquired while operating across diverse markets, competitive environments, and cultural contexts. These experiences collectively strengthen a firm's strategic decision-making and operational efficiency. Lu and Beamish (2001) found a direct positive relationship between international diversification and SME performance, measured by indicators such as sales growth and profitability. Their findings argue that international expansion allows SMEs to spread risk and access new customer segments, resulting in higher growth rates than firms that remain focused on domestic markets. In addition, Vahlne and Johanson's (2017) influential work on the internationalisation process model—also known as the Uppsala model—emphasises that a step-by-step approach enables firms to gradually accumulate knowledge and resources. This progressive development improves operational efficiency and contributes to stronger performance outcomes. In summary, while there is broad agreement on the positive impact of internationalisation on SME performance, the magnitude of this effect may vary depending on other influencing factors. Drawing on the theoretical and empirical foundations outlined, the following hypothesis is proposed:

Hypothesis 5: There is a positive relationship between the level of internationalisation of SMEs and their performance.

This hypothesis is based on the premise that international expansion does more than open new markets—it strengthens a firm's innovative capacity, operational effectiveness, and strategic flexibility, all of which are essential drivers of performance.

Fig. 1 presents the research model, illustrating the hypothesised relationships between entrepreneurial orientation (EO), performance (PER), AI adoption (AIA), and internationalisation (INT). These hypotheses are tested in the context of SMEs in the Visegrad chemical sector, a setting that exemplifies the challenges and opportunities faced by firms in transitional economies and technology-intensive industries. However, the relationships explored are broadly applicable to SMEs operating in similar regional and sectoral environments.

3. Methodology and Data

Building on the foundations of previous scholarship examining the link between entrepreneurial orientation (EO) and firm performance (Gupta and Wales, 2017; Lumpkin and Dess, 1996), this study adopts a quantitative research approach to investigate this relationship within the chemical industry of the Visegrad region. Following a similar line of inquiry to Baldegger et al (2020), the author developed a research model that extends the analysis to include internationalisation and AI adoption among SMEs in the region.

The study's research design employs a comprehensive, questionnaire-based methodology. It incorporates established scales for measuring EO (Covin and Slevin, 1989), performance, and internationalisation (Baldegger et al, 2021), along with newly developed items to assess AI adoption. This combination of traditional and innovative measures aims to provide a well-rounded understanding of the factors shaping SME performance in the context of technological transformation and global market engagement.

3.1 Context of the Study: The Visegrad Region and the Chemical Industry

The Visegrad Group (V4), comprising the Czech Republic, Hungary, Poland, and Slovakia, offers a distinctive and compelling context for studying entrepreneurial orientation (EO), AI adoption, and internationalisation in SMEs. Several factors make this region particularly suitable for examining these dynamics.

First, the Visegrad countries have undergone significant economic transformation, shifting from centrally planned to market-oriented economies. This transition has created fertile ground for entrepreneurial activity, characterised by innovation, proactiveness, and risk-taking (Hudec, 2015). The region's combination of emerging market dynamics and European Union (EU) integration pro-

vides a rich environment for examining how EO influences firm behaviour in the face of rapid economic change.

Second, the chemical sector in the Visegrad region holds strategic importance. It makes a substantial contribution to GDP, employment, and technological advancement (Cefic, 2024). SMEs in this sector play a pivotal role in supply chains and are often among the first to adopt new technologies to maintain competitiveness. The industry's complexity and ongoing need for innovation make it an ideal setting for exploring the links between EO and AI adoption.

Lastly, the intersection of regional entrepreneurial characteristics and the chemical industry's technological demands creates a unique empirical setting. This environment enables in-depth exploration of how EO influences SME performance, AI adoption, and internationalisation—three dimensions that are critically interlinked in this sector. The insights gained from this research may have broader implications for SMEs operating in other transitional economies and technology-driven industries.

By empirically testing these relationships in the Visegrad chemical sector, the study aims to deliver a comprehensive understanding of the region's entrepreneurial dynamics and contribute to wider debates on the competitiveness of SMEs in similar economic and industrial contexts.

3.2 Sample and Data Collection

In an effort to contribute to the relatively underexplored field of entrepreneurship in Central Europe's chemical industry, the author selected a sample of small and medium-sized enterprises (SMEs) defined by the following nomenclature statistique des activités économiques dans la Communauté européenne (NACE) codes: NACE 20 – Manufacture of chemicals and chemical products; NACE 21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations; NACE 22 – Manufacture of rubber and plastic products (European Parliament, 2006), using the Orbis database (Bureau van Dijk, 2023).

The definition of SME varies across regions, and even within the European Union (EU), the application of the official definition is inconsistent. This study follows the official EU definition set out in Recommendation 2003/361 (European Commission, 2003): a small enterprise employs fewer than 50 people and has either an annual turnover or balance sheet total not exceeding €10 million; a medium-sized enterprise employs fewer than 250 people and has either an annual turnover not exceeding €50 million or a balance sheet total not exceeding €43 million. Data that met these criteria were filtered from Orbis, which is regarded as one of the world's most comprehensive sources of comparable information on more than 400 million private companies. Orbis was considered especially suitable for this research due to its detailed focus on the European market and its extensive financial information on more than 19 million European companies (Bureau van Dijk, 2023).

Access to Orbis was granted through the author's university, which holds a paid institutional licence. Contact details, including email addresses of potential participants, were retrieved from designated database fields.

A total of 5149 companies initially met the inclusion criteria. However, 157 were excluded either due to missing email addresses or because they were identified as majority-owned subsidiaries of larger multinational enterprises, and therefore did not meet the requirement of independence. This reduced the final sample to 4992. The data collection phase was conducted between September and October 2023. To maximise participation and accommodate linguistic diversity, the questionnaire was translated into the four regional languages—Czech, Slovak, Polish, and Hungarian—and distributed via a recognised platform, Mailchimp (The Rocket Science Group, 2024). Translation quality was reviewed by groups of 3–5 native speakers for each language, resulting in minor adjustments. This approach enhanced inclusivity and was likely to improve the response rate, thereby strengthening the reliability and depth of the dataset. A locally tailored invitation to complete the Google Forms-based online questionnaire (Alphabet Inc., 2024) was addressed to the general manager or highest-ranking officer, in line with established practice (Saunders et al, 2023), as senior executives typically have the most accurate strategic overview of their firms. To reach the minimum required sample size, two follow-up reminders were sent, and the author personally conducted an average of 100 calls per week during the collection period. Despite these efforts, the final response rate was 2.72%, resulting in 136 completed questionnaires. This relatively low response rate can be attributed to several factors. While the email addresses from Orbis were assumed to be current, many were not direct contacts for senior executives, who may be reluctant to participate in unsolicited surveys. Additionally, the use of Mailchimp, although well regarded, may have led to emails being flagged as spam—a risk previously noted by Casillas et al (2011). Nonetheless, the data collection methods were consistent with standard best practices, increasing the overall credibility of the findings. The minimum required sample size was determined using the G*Power statistical tool (version 3.1.9.7; Heinrich Heine University Düsseldorf, Düsseldorf, North Rhine-Westphalia, Germany) (Faul et al, 2009), based on an α-level of 0.05, a medium effect size (f = 0.15), and a power level of 0.8. This calculation indicated that a minimum of 114 responses was required, which the final sample exceeded. No statistically significant differences were identified between responders and non-responders with respect to company size and revenue, suggesting that non-response bias was not present (Saunders et al, 2023).

3.3 Measures

To investigate the relationships between entrepreneurial orientation (EO)—the sole independent

Table 1. Entrepreneurial Orientation Evaluation Framework.

Code	Indicator Name	Description	Question	Answer Options
IN1	Innovative Mindset	Gauge of management's inclination towards innovation	How would you describe the approach of your firm's top managers?	1 = Primarily Marketing Tried and True Products 7 = Primarily Focused on Technological Leadership and Innovation
IN2	Product Evolution	Evaluation of the firm's history in evolving its product/service offerings	How would you describe your firm's track record in launching new lines of products or services over the past five years?	1 = No New Launches 7 = Frequent New Launches
IN3	Adaptability Index	Measure of the firm's responsiveness to market changes	How significant have the changes to your firm's product or service lines been in the past five years?	1 = Minor Changes 7 = Dramatic Changes
PR1	Market Foresight	Assessment of the firm's anticipation and response to competitive actions	How proactive is your firm in dealing with competitors?	1 = Mainly Reactive to Competitors 7 = Mainly Proactive, Initiating Actions
PR2	Leadership Influence	Insight into the firm's status as a thought leader compared to peers	How often is your firm the first to introduce new products, services, or technologies compared to competitors?	1 = Very Seldom 7 = Very Often
PR3	Strategic Boldness	Degree of the firm's assertiveness in competitive strategies	In the competitive landscape, is your firm more aggressive or conservative?	1 = Conservative, Prefers to Avoid Clashes 7 = Aggressive, Takes on Competitors
RI1	Risk Appetite	Level of the firm's willingness to engage in high-stakes projects	How inclined are the top managers of your firm toward taking on high-risk, high-reward projects?	1 = Prefer Low-Risk Projects 7 = Prefer High-Risk Projects
RI2	Strategic Prudence	Extent of caution exercised in strategic decision-making	How do your top managers approach strategic decisions, given the business environment?	1 = Prefer Incremental Steps 7 = Prefer Bold, Wide-ranging Acts
RI3	Decision Momentum	Speed and resolution in the firm's decision-making processes	How does your firm approach decision-making in uncertain situations?	1 = Cautious, Wait-and-See 7 = Bold, Aggressive

Source: (Covin and Slevin, 1989). IN, innovation; PR, proactiveness; RI, risk-taking.

Table 2. Company Performance Assessment Framework.

Code	Indicator Name	Description	Question	Answer Options
SG1	Sales Growth	Annual increase in company sales	What was the sales growth of your company between the last two full years?	Decline greater than 10% Decline up to 10% Stable (±5%) Growth up to 10% Growth greater than 10%
SG2	Market Growth	Sales growth comparison with industry competitors	How would you rate your company's sales growth between the last two full years compared to competitors?	1 = Significantly Lower 5 = Significantly Higher
EG	Staff Growth	Rate of increase in the number of employees	How has the number of employees in your company changed between the last two full years?	Reduced by more than 10% Reduced by up to 10% Remained the same Grew by up to 10% Grew by more than 10%

Source: (Baldegger et al, 2021). SG, sales growth; EG, employee growth.

variable—and the three dependent variables (performance, internationalisation, and artificial intelligence [AI] adoption), this study employed multi-item scales with forced-choice response formats. All scales, except for that measuring AI adoption, are well-established and widely used in social science research, and are thus assumed to possess validity and reliability (Rauch et al, 2009). The measure for AI adoption, as a relatively new construct, was developed and tested using Churchill's (1979) framework.

To ensure measurement clarity and accuracy, different Likert-scale formats were applied. A 7-point Likert scale was used for both the independent variable (EO) and the newly developed AI adoption scale to maintain alignment with the literature on EO. Other dependent variables, such as performance, as well as control variables, were measured using established 5-point Likert scales. This tailored approach balances methodological consistency with construct-specific requirements. All response options for each variable are presented in Tables 1,2,3,4,5.

3.3.1 Independent Variable

EO, as conceptualised by Miller (1983), includes three primary dimensions: innovativeness, proactiveness, and risk-taking. This study adopts the well-known Covin and Slevin (1989) scale, consisting of nine items aligned with those dimensions (see Table 1). The scale has been validated across industries and regions, confirming its reliability (Rauch et al, 2009). It serves here as a central tool for measuring EO within SMEs in the Visegrad chemical industry, capturing the firm's tendency toward innovation, forward-looking strategy, and risk propensity.

Each item used a 7-point forced-choice Likert scale, where lower scores typically reflect a more conservative posture and higher scores reflect more entrepreneurial behaviour. To reduce interpretation bias, each item was carefully contextualised in the questionnaire. For example, participants were asked to describe their firm's approach to strategic decision-making (e.g., '1 = Prefer incremental steps, 7 = Prefer bold, wide-ranging acts') or innovation history (e.g., '1 = No new launches, 7 = Frequent new launches'). Higher composite scores reflect stronger entrepreneurial orientation, allowing for a nuanced evaluation of how innovativeness, proactiveness, and risk-taking shape the firm's strategic stance in the evolving landscape of the Visegrad chemical sector.

Although the theoretical section discusses five EO dimensions—including competitive aggressiveness and autonomy—the empirical analysis in this study applies the three core dimensions: innovativeness, proactiveness, and risk-taking. This decision aligns with prevailing EO research practice. For instance, White et al (2021) note that while the five-dimensional model explains slightly more variance, the difference is not statistically significant. Moreover, 76% of EO studies adopt the three-dimensional model, enhancing comparability across the literature.

By adopting the three-dimensional model, this study maintains strong comparability with previous research, ensuring that findings are grounded in widely accepted methodological standards. At the same time, the exclusion of competitive aggressiveness and autonomy may slightly reduce the comprehensiveness of EO measurement. Nonetheless, the selected dimensions provide a robust foundation for examining entrepreneurial orientation among SMEs in the Visegrad chemical sector.

3.3.2 Dependent Variables

PERFORMANCE - in the field of business and entrepreneurship, performance is widely recognised as a complex and multidimensional construct. While many definitions exist, most scholars agree that performance should not be reduced to a single financial metric but should instead encompass various dimensions of organisational success (Rauch et al, 2009). Although objective financial indicators have traditionally dominated measurement approaches,

Table 3. International Market Penetration Framework.

Code	Indicator Name	Description	Question	Answer Options
IS	Int. Sales	Proportion of sales attributed to international markets	What percentage of your total sales is from international markets?	0–10% 11–25% 26–50% 51–75% More than 75%
CO	Int. Markets	Number of countries where the company is actively selling products or services	In how many different countries does your company currently provide products or services?	Provide total number
CN	Global Footprint	Number of global regions with active company operations	On how many continents is your company actively operating? Please provide the total number of continents.	Provide total number

Source: (Baldegger et al, 2021). IS, international sales; CO, countries; CN, continents.

they may not fully reflect a firm's broader development trajectory—particularly in terms of growth and market presence.

As Baldegger et al (2021) argue, over-reliance on financial indicators may obscure important strategic aspects of firm performance, such as innovation or competitive positioning. As a result, there has been a growing shift towards the use of subjective performance measures. These self-assessments have been shown to correlate strongly with objective data, supporting their validity as indicators of firm success. Following this approach, the present study adopts the simplified subjective performance scale proposed by Baldegger et al (2021), as outlined in Table 2. This scale enables the exploration of self-perceived aspects of performance, offering a more holistic perspective by incorporating the insights of SME leaders alongside observable business outcomes. The response format was adapted to suit the nature of each variable. For example, sales growth was measured using categorical responses: 'Decline greater than 10%', 'Decline up to 10%', 'Stable (±5%)', 'Growth up to 10%', and 'Growth greater than 10%'. Alternative answer formats for all dependent and control variables are presented in Tables 1,2,3,4,5.

In this way, the study bridges the gap between financial robustness and strategic development, providing a comprehensive lens through which to assess SME performance in the Visegrad chemical industry.

INTERNATIONALISATION - In business research, internationalisation has traditionally been measured using single indicators—most commonly, the proportion of export sales to total sales. This approach, exemplified by Riahi-Belkaoui (1998), provides a useful but limited view. In contrast, contemporary scholars such as Dörrenbächer (2000) advocate for composite measurements that more accurately reflect the multidimensional nature of internationalisation. This study adopts both a performance indicator—the export sales ratio—as used by Riahi-Belkaoui (1998) and Marshall et al (2020), and structural indicators to capture the geographic dispersion of a firm's activities, following the approach of Baldegger et al (2021) and Kuivalainen et al (2012).

The selected indicators, summarised in Table 3, offer a comprehensive assessment of internationalisation. The export sales ratio reflects the firm's economic engagement in foreign markets, while the number of active countries and continents provides insight into the spatial reach and strategic scope of international operations. Together, these indicators capture both the scale and structure of international activity among SMEs in the chemical industry. This dual approach offers a more nuanced understanding of internationalisation by considering both economic and geographical dimensions—factors that are particularly relevant in cross-national studies of SMEs.

AI ADOPTION - In developing the measure for AI adoption within SMEs, an initial review of the literature revealed a notable gap: no existing scale adequately captured the construct in the context of this study. To address this, the research followed Churchill's (1979) methodological framework for questionnaire development—a widely respected approach in academic research. This framework, also employed by Javalgi and Todd (2011) in their work on internationalisation and EO in Indian SMEs, involves extensive literature review, pretesting, and iterative refinement of survey items.

Given the absence of an established instrument, a bespoke scale was developed. This process was informed by findings from a preceding pilot study (Hruby, 2024), which provided empirical insights into AI adoption dynamics in SMEs. Although not the focus of this paper, the pilot study significantly contributed to the conceptual clarity and relevance of the scale, enhancing its construct validity.

This bespoke scale, resonating with the tri-dimensional structure of EO, focuses on innovativeness, proactiveness, and risk-taking in the context of AI adoption. The scale's items, detailed in the summary Table 4, are structured to capture the essence of AI adoption in a manner directly relevant to the study's focus.

Table 4. AI Adoption Framework.

Code	Indicator Name	Description	Question	Answer Options
AI1	AI-Driven Innovativeness	Degree of innovation through AI technology adoption in products/services	Has your firm adopted AI (artificial intelligence) technologies to innovate your product or service offerings?	1 = Not at All 7 = Extensively
AI2	AI Strategic Proactiveness	Level of forward-planning for AI implementation within business operations	Is your firm actively planning to use AI (artificial intelligence) in business operations within the next 12 months?	1 = Not at All 7 = Definitely
AI3	AI Risk Propensity	Openness to investing in emerging and potentially risky AI technologies	Is your firm willing to adopt AI (artificial intelligence) technologies that are still emerging and less established?	1 = Not at All 7 = Absolutely

Source: (Hruby, 2024). AI, artificial intelligence.

Table 5. Control Variables Framework.

Code	Indicator Name	Description	Question	Answer Options
CV1	Age	Years of operational history	How many years has your company been in operation?	Less than 1 year 1–5 years 6–10 years 11–20 years More than 20 years
CV2	Size	Current workforce size	How many employees does your company currently have?	1–10 11–50 51–100 101–200 More than 250
CV3	Country	Primary country of business operations	In which country is your company primarily located?	Drop down list of countries
CV4	Industry	Primary NACE code	Data retrieved from Orbis database	-

Source: (Weerakoon, 2023). CV, control variable; NACE, nomenclature statistique des activités économiques dans la Communauté européenne.

Innovativeness: Mirroring the spirit of EO, this dimension measures the extent of AI-driven innovation in products or services, embodying the creative integration of AI within the firm's offerings.

Proactiveness: Reflecting a forward-looking stance, this aspect assesses the firm's intent to integrate AI into future operations, indicating a proactive approach towards AI-driven transformation.

Risk-taking: This dimension gauges the extent of a firm's investment in AI amidst financial uncertainties, capturing the risk aspect associated with AI adoption.

The rationale for this focused approach—rather than using broader indicators of digital readiness or general technological awareness—was to ensure conceptual consistency with EO. This alignment is consistent with recent research, including Alekseeva et al (2020) and Chatterjee et al (2021), which identifies nuanced relationships between managerial strategy, digital capability, and organisational dynamics in AI adoption. By anchoring the AI adoption scale within the EO framework, the study fills a critical gap in the literature and offers a conceptually grounded tool for examining the strategic dimensions of AI integration in SMEs.

3.3.3 Distinction and Measurement of EO and AI Adoption

EO is conceptualised as a firm's strategic posture towards entrepreneurship, characterised by the dimensions of innovativeness, proactiveness, and risk-taking (Covin and Slevin, 1989). In contrast, AI Adoption Orientation is defined as a firm's strategic approach to adopting AI technologies, encompassing AI-driven innovativeness, AI strategic proactiveness, and AI risk propensity. While both constructs draw on similar strategic principles, they represent distinct applications in entrepreneurial and technological contexts. EO was measured using the well-established nine-item scale by Covin and Slevin (1989). In contrast, the measure for AI Adoption Orientation was newly developed and validated through pilot testing, with a specific focus on strategic behaviours related to AI implementation.

To confirm that EO and AI Adoption Orientation are conceptually distinct, both correlation testing and discriminant validity analysis were performed. Correlation analysis indicated moderate relationships between the constructs, supporting the interpretation that while related, they measure different phenomena. Discriminant validity was assessed using the Heterotrait-Monotrait ratio (HTMT). All

HTMT values were below the threshold of 0.85, confirming that EO and AI Adoption Orientation are statistically distinct constructs. Reliability and validity were further tested using Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE). Results indicated strong internal consistency and acceptable levels of convergent validity for both constructs, ensuring the robustness of the measures.

3.3.4 Control Variables

The inclusion of control variables—age, size, country, and industry—follows best practices in quantitative research, ensuring that the observed effects of EO on dependent variables are not confounded by external influences. Control variables help isolate the specific contribution of the independent variable to the model, enhancing the precision and validity of the findings (Weerakoon, 2023).

Firm age reflects a company's stage in the business lifecycle, which can influence strategic decision-making and market experience. Older firms may demonstrate different EO profiles compared to younger ones (Lumpkin and Dess, 2001). Established routines and resource availability can enable strategic innovation, including AI adoption, but may also inhibit change due to organisational inertia (Kocak et al, 2017). Moreover, older firms often have stronger networks and greater resources, which can enhance international performance, though their more conservative stance may limit agility in rapidly changing markets (Gerschewski et al, 2015).

Firm size, measured by the number of employees, provides insight into internal resources and operational capacity. Larger firms tend to have more resources for investing in AI, which can lead to improved performance and competitiveness (Dubey et al, 2020). At the same time, smaller firms may outperform larger ones in volatile environments due to their agility and proactiveness (Kraus et al, 2012). While large firms often adopt lower-risk innovation strategies, smaller ones may pursue higher-risk, higher-reward ventures (Marom et al, 2019).

Country serves as a contextual variable, accounting for regional and cultural influences on SME strategy and behaviour (Xiao et al, 2023). Differences in regulatory environments and technological readiness can affect innovation adoption. For instance, developing countries may benefit more from government support and infrastructure in facilitating innovation diffusion (Zhu et al, 2006). EO expression can also differ significantly by country due to economic and institutional factors (Civelek et al, 2020). Access to public financial support is often positively associated with higher export intensity in different European regions (Ciszewska-Mlinaric, 2018).

Although the study focuses on three closely related NACE codes, industry is included as a control to account for subtle differences across subsectors. Regulatory dynamics and market competition within specific industry segments can influence innovation adoption patterns and overall firm performance. For example, industry-specific pressure and technological demands affect how firms engage with new technologies, including AI (Dubey et al, 2020; Wu et al, 2003; Zhu et al, 2006).

3.4 PLS-SEM Methodology

The data analysis was conducted using Partial Least Squares Structural Equation Modelling (PLS-SEM), a method particularly well-suited for exploratory research and models involving formative constructs (Chin, 1998; Roldán and Sánchez-Franco, 2012). PLS-SEM is especially appropriate for this study due to its flexibility in handling complex models and smaller sample sizes, as well as its emphasis on maximising the explained variance of dependent variables. This method aligns with the research objectives, offering robust analytical capabilities without requiring the strict assumptions typical of covariance-based SEM approaches (Reinartz et al, 2009).

3.5 Ethical and Methodological Overview

Ethical considerations—particularly regarding informed consent and data confidentiality—were central to the study's design. All participants were informed about the study's purpose, their voluntary involvement, and the confidentiality of their responses, ensuring compliance with established ethical research standards.

In summary, the chosen quantitative methodology, which employs a multilingual, questionnaire-based design targeting SMEs in the chemical sector of the Visegrad region, is well-suited to explore the relationships between EO, AI adoption, internationalisation, and firm performance. This approach is expected to generate meaningful insights into the strategic and operational dynamics that shape SME competitiveness in a transitional and technology-intensive environment.

4. Results

To investigate the interplay between entrepreneurial orientation (EO), artificial intelligence adoption (AIA), internationalisation (INT), and performance (PER) among SMEs in the Visegrad region's chemical sector, data from 136 firms were collected and analysed. This chapter serves two key purposes: first, to describe the sample using descriptive statistics, and second, to evaluate the proposed hypotheses using the PLS-SEM technique implemented in SmartPLS (Ringle et al, 2022). This approach provides a robust analytical framework for examining the relationships between constructs within this specific regional and industrial context.

4.1 Descriptive Statistic of the Visegrad Chemical Industry

The dataset was generated using a structured questionnaire comprising 22 items. The first four questions captured control variables, including firm age, size, country, and in-

Table 6. Descriptive Statistics.

Variable	Mean	Min	25%	Median	75%	Max	Mode	Mode Freq.
EO	32	10	25	34	39	56	33	9
PER	10	3	8	10	12	15	9	31
AIA	7	3	3	5	9	21	3	41
INT	9	3	3	6	11	57	3	40
Age	n/a	<1	11–20	20+	20+	20+	20+	95
Size	n/a	1–10	1–10	11–50	11–50	101–249	11–50	57
Country	n/a	SK	n/a	n/a	n/a	HU	HU	51
Industry	n/a	Pharma	n/a	n/a	n/a	Plastics	Plastics	62

INT, Internationalization; SK, Slovakia; HU, Hungary.

Table 7. Correlation Matrix.

	EO	PER	AIA	INT	Age	Size	Country	Industry
EO	1							
PER	0.163	1						
AIA	0.384**	0.032	1					
INT	0.258**	0.049	0.147	1				
Age	0.077	0.001	0.104	0.174*	1			
Size	0.235**	0.091	0.230**	0.457**	0.379**	1		
Country	0.156	0.236**	0.049	–0.175*	–0.121	–0.187*	1	
Industry	0.036	–0.111	0.046	0.118	0.091	0.115	–0.193*	1

Note: * Significant at $p < 0.05$; ** Significant at $p < 0.01$.

dustry. Respondents selected from predefined ranges, enabling straightforward coding for statistical analysis. The remaining 18 variables covered the four central theoretical constructs of the study, assessed using 7-point Likert scales to capture managerial perceptions and strategic behaviours. The data consisted of both nominal (e.g., country, industry) and ordinal responses and did not follow a normal distribution. As a result, non-parametric statistical methods were employed to accommodate the characteristics of the dataset.

The sample was composed primarily of mature firms, with the most frequent age category being "20 years and over", indicating established market presence. In terms of firm size, the most common group was those with 11–50 employees. Geographically, the firms were well-distributed across the Visegrad countries, with the highest concentration in Hungary, followed by the Czech Republic. Sector-wise, firms from the plastics industry were most prevalent (see Table 6).

EO exhibited a median score of 34, ranging from 10 to 56, suggesting a broad spectrum of entrepreneurial postures—from conservative to highly entrepreneurial. Scores clustered around the 25–40 range, indicating diversity in innovation and risk-taking across firms. Performance scores were generally high, with a median of 10 and a slight left skew, suggesting that most firms rated their performance favourably. AI adoption, with a median score of 5 and a range from 3 to 21, revealed a right-skewed distribution. This indicates that while many firms are at early stages of AI integration, a few have adopted it more extensively. Internationalisation scores also showed wide variation, with a concentration at lower levels (scores around 3 to 6), but with some firms operating extensively across borders, as reflected by the long right tail of the distribution.

The Spearman correlation matrix in Table 7 provides insight into the relationships between the key constructs and control variables in this study of SMEs in the Visegrad chemical sector. Notably, there is a strong positive correlation (0.457) between firm size and internationalisation, suggesting that larger firms are more active internationally, likely due to greater resources and capacity for cross-border operations. A significant positive correlation (0.384) also exists between EO and AI adoption, indicating that firms with stronger entrepreneurial orientations are more inclined to adopt AI technologies—presumably as part of a broader innovation strategy.

The data further show a moderate positive relationship (0.236) between country of operation and performance, suggesting that local economic and institutional environments influence SME success. Additionally, EO and internationalisation are positively correlated (0.258), reinforcing the idea that entrepreneurial firms are more likely to expand internationally. A notable correlation is also observed between firm age and size (0.379), aligning with the expectation that older firms tend to be larger due to accumulated resources and experience.

Despite these statistically significant relationships, a considerable portion of the sample reported low AI adoption scores, highlighting potential barriers such as cost, lack of expertise, or perceived irrelevance. These results underscore the complexity of firm behaviour in social science

Table 8. Reliability and Validity Metrics for Construct Assessment.

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
AIA	0.845	0.852	0.906	0.764
EO	0.907	0.910	0.924	0.573
INT	0.793	0.802	0.879	0.710
PER	0.646	0.731	0.801	0.581

Table 9. HTMT Matrix for Assessing Discriminant Validity.

	EO	PER	AIA	INT	Age	Size	Country	Industry
EO								
PER	0.320							
AIA	0.449	0.129						
INT	0.282	0.146	0.171					
Age	0.091	0.124	0.110	0.170				
Size	0.268	0.143	0.225	0.528	0.308			
Country	0.186	0.285	0.079	0.130	0.125	0.161		
Industry	0.056	0.126	0.0414	0.076	0.047	0.1036	0.189	

HTMT, Heterotrait-Monotrait ratio.

research, where multiple contextual factors influence observed outcomes—many of which extend beyond the scope of the data collected (Senthilnathan, 2019).

4.2 Reliability and Validity Tests

To assess construct reliability and validity, the study employed several widely accepted metrics, including Cronbach's alpha, composite reliability (rho_a and rho_c), and Average Variance Extracted (AVE). These indicators were used to evaluate the internal consistency and convergent validity of the four main constructs: EO, AI adoption, internationalisation, and performance (see Table 8).

Cronbach's alpha values showed strong internal consistency for all constructs, except for performance (PER), which was slightly below the generally accepted threshold of 0.70. Nevertheless, PER achieved acceptable levels in both composite reliability measures, confirming its suitability for inclusion in the analysis.

The AVE values for AI adoption and internationalisation were well above the 0.50 threshold, indicating a high level of convergent validity. Although AVE values for EO and PER also exceeded the minimum requirement, they were relatively lower, suggesting that these constructs explain a slightly smaller proportion of variance in their respective indicators. These results support the robustness of the measurement model and justify its application in the subsequent structural analysis.

To assess discriminant validity, the Heterotrait-Monotrait ratio (HTMT) was used. HTMT values provide a rigorous test of whether different constructs in a model are empirically distinct. Ideally, these values should remain below 0.85 to indicate that the constructs measure separate concepts.

In this study, the HTMT value between AI adoption and EO was 0.449—well below the critical threshold—demonstrating that the two constructs are statistically distinct. EO captures a firm's broader entrepreneurial posture, whereas AI adoption reflects specific strategic behaviours related to technology use.

This distinction reinforces the conceptual framework of the study: EO is positioned as a key enabler of innovation and risk-taking, while AI adoption represents one possible strategic outcome influenced by EO. The full HTMT matrix is presented in Table 9 and supports the discriminant validity of all constructs included in the model.

4.3 Structural Model Assessment

The completion of the dataset, encompassing 136 responses to 22 questions, facilitated the construction and assessment of the structural model in Smart PLS (Version 4.0.9.7, SmartPLS GmbH, Bönningstedt, Germany), as delineated in Fig. 2.

This analytical phase yielded the structural model path estimates, with the significance of path coefficients meticulously verified through a 95% bootstrap confidence interval using a two-tailed test across 5000 runs. The resulting model allows for the evaluation of the hypothesised relationships between EO, AI adoption, internationalisation, and performance. Detailed results are presented in Table 10, providing the foundation for hypothesis testing and analysis of control variable effects.

4.3.1 Hypothesis Testing

Hypothesis 1 (H1): There is a positive relationship between the entrepreneurial orientation and performance of SMEs in the chemical industry in the Visegrad region.

The analysis supports H1, revealing a significant positive effect (path coefficient: 0.236, p-value: 0.034), thereby confirming a statistically significant relationship between entrepreneurial orientation and performance.

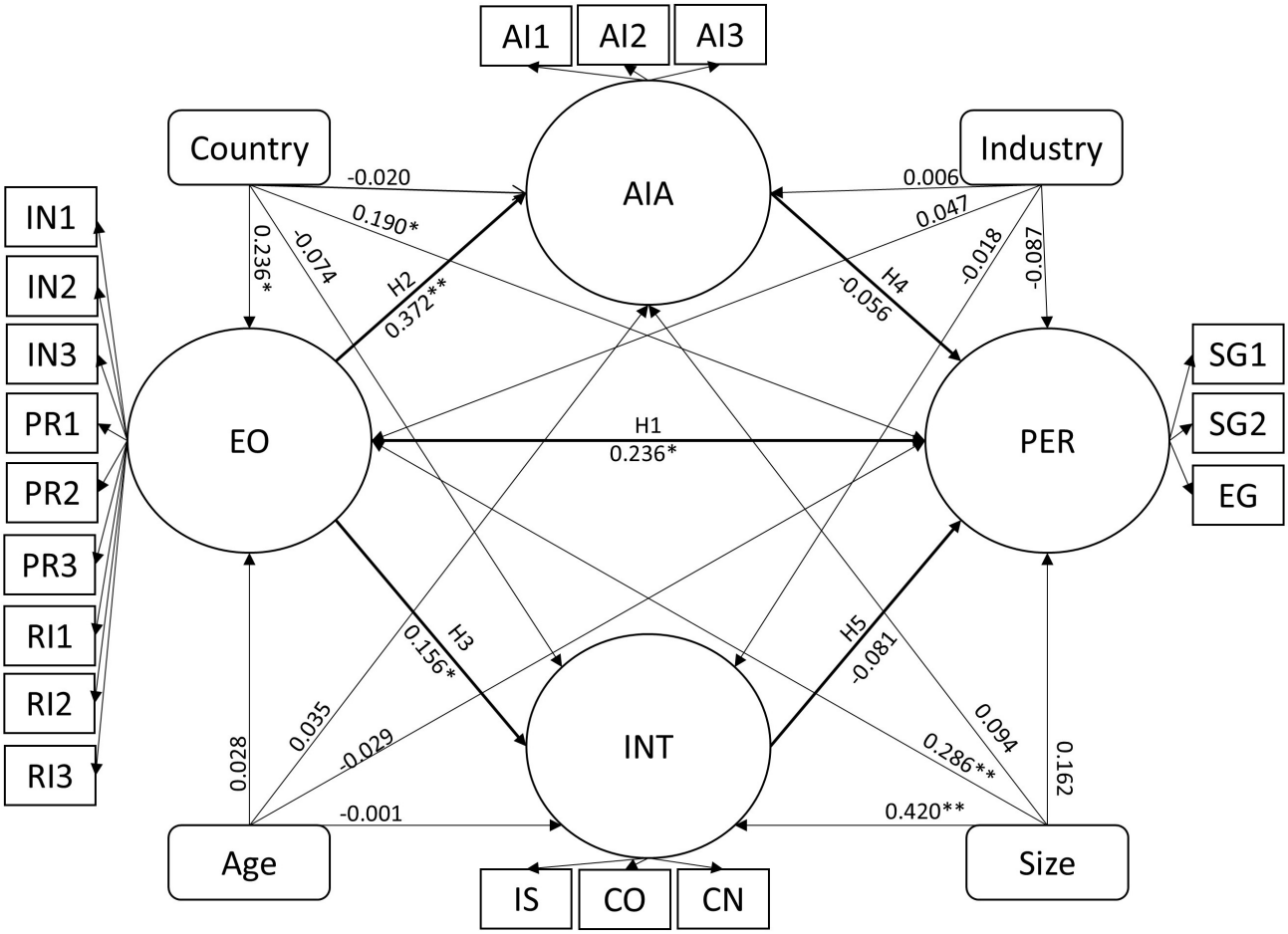

Fig. 2. Structural Model Paths. * Significant at $p < 0.05$; ** Significant at $p < 0.001$.

Table 10. Path Coefficients and Significance Levels.

	EO	PER	AIA	INT
EO				
PER	0.236*			
AIA	0.372**	–0.056		
INT	0.156*	–0.081		
Age	0.028	–0.029	0.035	–0.001
Size	0.286**	0.162	0.094	0.420**
Country	0.236*	0.190*	–0.020	–0.074
Industry	0.047	–0.087	0.006	–0.018

Note: * Significant at $p < 0.05$; ** Significant at $p < 0.001$.

Hypothesis 2 (H2): There is a positive relationship between the entrepreneurial orientation of SMEs in the chemical industry of the Visegrad region and their likelihood to adopt AI technologies.

This hypothesis is strongly supported, with a significant and positive path coefficient of 0.372 ($p < 0.001$), suggesting a robust relationship between EO and AI adoption.

These results demonstrate that although EO influences both performance and AI adoption, each relationship is analytically distinct. EO contributes independently to different strategic outcomes within the firm.

Hypothesis 3 (H3): There is a positive relationship between the entrepreneurial orientation of SMEs in the chemical industry of the Visegrad region and their level of internationalisation.

H3 is supported, with a significant positive effect (path coefficient: 0.156, *p*-value: 0.044), reinforcing the view that EO is associated with a greater degree of international engagement.

Hypothesis 4 (H4): There is a positive relationship between the adoption of artificial intelligence by SMEs in the Visegrad chemical industry and their performance.

The analysis does not support H4. The path coefficient (–0.056) is non-significant (*p*-value: 0.551), indicating no statistically meaningful link between AI adoption and performance in the current dataset.

Hypothesis 5 (H5): There is a positive relationship between the level of internationalisation of SMEs in the chemical industry of the Visegrad region and their performance.

H5 is also not supported. The relationship between internationalisation and performance is statistically insignificant (path coefficient: –0.081, *p*-value: 0.409), suggesting that internationalisation does not have a direct impact on performance within this sample.

4.3.2 Impact of Control Variables

The analysis also reveals several significant relationships involving the control variables, as summarised in Table 10.

Firm age has a positive but non-significant relationship with EO ($\beta = 0.028$, $p > 0.05$), suggesting that while older firms may possess more experience and resources, this does not necessarily lead to stronger entrepreneurial orientation.

Firm size shows a significant positive effect on both EO ($\beta = 0.286$, $p < 0.001$) and internationalisation ($\beta = 0.420$, $p < 0.001$), indicating that larger firms are more entrepreneurial and more engaged in international markets—likely due to greater capacity to absorb risk and invest in growth.

The country variable significantly affects both EO ($\beta = 0.236$, $p < 0.05$) and performance ($\beta = 0.190$, $p < 0.05$), reinforcing the importance of national context in shaping entrepreneurial behaviour and outcomes.

Industry was not a significant predictor for any of the dependent variables, suggesting that within this tightly defined sector, inter-industry differences have minimal impact compared to firm-level and country-level characteristics.

5. Discussion

This study, Entrepreneurial Orientation in the Age of Artificial Intelligence: A Study of SMEs in the Visegrad Chemical Sector, examined the complex relationships between entrepreneurial orientation (EO), artificial intelligence (AI) adoption, internationalisation, and SME performance within a Central European context. The purpose of this discussion is to interpret the results, explore their implications for theory and practice, and reflect on the broader significance of the findings.

A significant gap in the literature was addressed by evaluating how EO influences both performance and strategic behaviours—specifically AI adoption and internationalisation—within a relatively underexplored geographical and industrial context. Drawing on a novel AI adoption scale developed through a pilot study (Hruby, 2024), this research offers insight into how SMEs in the Visegrad region's chemical industry navigate emerging technologies and global expansion under varying entrepreneurial postures.

The discussion integrates the findings with existing literature, considers implications for SME leaders, policymakers, and industry stakeholders, and highlights the broader role of AI within entrepreneurial ecosystems. It also reflects on study limitations and proposes future research directions.

The findings provide both confirmation and refinement of existing theories regarding EO and its strategic outcomes. The strong support for Hypotheses 1, 2, and 3 confirms that EO plays a central role in enhancing firm performance, encouraging AI adoption, and supporting internationalisation among SMEs. These results align closely with theoretical frameworks such as Dynamic Capabilities Theory, which emphasises a firm's ability to adapt and reconfigure resources in response to environmental change (Teece et al, 1997). EO enables SMEs to sense and seize international opportunities by continuously adjusting strategies and reconfiguring internal capabilities. This adaptability is especially valuable when firms operate across diverse and evolving international markets. For example, EO-driven firms may revise product offerings or marketing approaches to meet the unique needs of global customers—behaviours that reflect strategic agility and support competitive advantage.

These findings are also consistent with the Resource-Based View (RBV), which positions EO as a valuable, rare, and inimitable organisational resource that contributes to sustained performance (Barney, 1991). EO enables firms to capitalise on opportunities in AI and international markets by leveraging their unique innovation capabilities, risk tolerance, and proactive decision-making styles.

The Technology Acceptance Model (TAM) further supports the results related to AI adoption. Firms with a strong EO are more likely to perceive AI technologies as useful and manageable, increasing their likelihood of adoption (Davis, 1989). Entrepreneurial firms often interpret AI as a means to increase efficiency, lower costs, and support data-driven strategy—factors that contribute to long-term competitive positioning.

These theoretical insights underscore the importance of EO in driving both AI adoption and internationalization, highlighting the synergistic effects of these factors on SME performance. The study's findings align with the works of Baldegger et al (2020) and Dubey et al (2020), reinforcing the critical role of EO in fostering technological innovation and global market expansion. This integrated perspective offers a comprehensive understanding of how EO can be leveraged to achieve superior outcomes in an increasingly digital and globalized business environment.

Hypotheses 1 and 2 were robustly supported, confirming a positive relationship between EO and both SME performance and AI adoption. This underscores the critical role of EO in driving performance and technological innovation, aligning with existing theories that position EO as a catalyst for competitive advantage and efficiency (Baldegger et al, 2020). The confirmation of Hypothesis 3 underscores the dynamic synergy between EO and internationalisation, illustrating how EO underpins not only local market success but also amplifies firms' global market presence. This result aligns with traditional models such as Vahlne and Johanson's Uppsala model, which posits that internationalisation is a gradual process that builds on accumulating knowledge and resources. However, my findings suggest that EO-driven firms may accelerate this process by leveraging their inherent innovativeness, proactiveness,

Table 11. Summary of Comparative Insights.

Key Findings	Alignment with Existing Studies	Extension or Contradiction
EO positively influences SME performance	Supports Rauch et al (2009); Wales (2016)	Highlights influence of regional factors in the Visegrad chemical sector
EO positively correlates with AI adoption	Aligns with Baldegger et al (2020); Dubey et al (2020)	Offers nuanced understanding in the chemical sector
No significant direct relationship between AI adoption and performance	Contradicts Shepherd and Majchrzak (2022); Baldegger et al (2020)	Suggests need for future research on temporal effects of AI adoption
EO positively impacts internationalisation	Supports Javalgi and Todd (2011); Brouthers et al (2015)	Highlights significant role of firm size in this relationship
Internationalisation does not directly enhance performance	Aligns with Liesch and Welch (2011)	Challenges assumption that global expansion automatically improves outcomes

and risk-taking capabilities, thus entering and performing in international markets more rapidly and effectively compared to the gradual step-by-step approach proposed by the Uppsala model. This indicates that while the Uppsala model emphasizes cautious and incremental internationalisation, EO provides a framework for a more dynamic and aggressive expansion strategy.

This view offers new insights into how EO can act as a catalyst for rapid internationalisation, suggesting that entrepreneurial SMEs are not necessarily bound by the incremental stages of internationalisation proposed by traditional models. Instead, they can leverage their strategic orientation towards entrepreneurship to achieve more immediate and impactful global market presence.

Conversely, Hypotheses 4 and 5 were not supported, challenging assumptions about the direct impact of AI adoption and internationalisation on performance enhancement. These findings suggest a need to re-evaluate the mechanisms through which AI and internationalisation contribute to SME performance, possibly indicating the influence of mediating factors or the existence of a more complex relationship than previously theorised. These results not only affirm the foundational importance of EO in SME success within the Visegrad chemical industry but also highlight the nuanced and sometimes unexpected pathways through which EO, AI adoption, and internationalisation interact.

The findings of this study align with Abbas et al (2023), reinforcing the significance of EO as a pivotal driver of SME performance in the chemical sector of the Visegrad region. This agreement with the works of Atluntas and Donmez (2010) and Hossain and Al Asheq (2019) underscores EO's essential role in fostering business practices that lead to superior outcomes. Furthermore, the study resonates with Wales (2016), demonstrating EO's broad applicability across various sectors, including chemicals, and underscores the unique economic and policy context of the Visegrad region as a significant influence in this dynamic.

The study also considered control variables to ensure a more robust analysis of EO, AI adoption, and SME internationalisation. Firm age showed no significant impact on EO, AI adoption, or internationalisation, aligning partially with expectations; while older firms have extensive resources and networks, their conservative tendencies may limit agility and innovation, as noted by Gerschewski et al (2015). Firm size, however, was found to positively influence EO and internationalisation, underscoring that larger firms, with more resources, are better equipped to pursue innovative and international strategies, as Dubey et al (2020) and Kraus et al (2012) observe. Interestingly, while larger firms could invest in AI, size alone did not have a significant impact on AI adoption, hinting that factors such as strategic orientation and market forces may play an equally critical role. The country variable significantly impacted EO and performance, affirming that national context—through economic conditions and regulatory support—shapes entrepreneurial activities and firm success (Autio et al, 2000; Zhu et al, 2006). Finally, industry did not show a notable influence on EO, AI adoption, or internationalisation, indicating that within the chemical sector, firm- and country-specific factors likely outweigh industry effects, as Zahra and Covin (1995) suggest.

5.1 Theoretical Contributions

The study contributes to the existing literature by providing new insights into the relationships between EO, AI adoption, internationalisation, and SME performance in the Visegrad chemical sector. By integrating multiple theoretical perspectives, the research enhances the understanding of how EO functions as a dynamic capability and a strategic resource that drives technological innovation and global market expansion.

Table 11 summarizes the key findings, their alignment with existing literature, and how they extend or contradict previous studies. The inclusion of the last effect concerning the internationalisation-performance link addresses the critical discussion on this relationship, as requested.

5.2 Guidelines for Managers

The study confirms that Entrepreneurial Orientation (EO) has a direct and significant positive impact on SME performance. Managers can capitalise on this finding by

implementing strategies that strengthen EO within their organisations to drive performance improvements. Cultivating an entrepreneurial culture is a key starting point. Managers should foster an environment that supports creativity and the development of new products, services, and processes. Encouraging innovativeness in this way can result in unique offerings that set the firm apart from competitors and meet emerging market needs. Promoting a proactive mindset among employees further strengthens EO by encouraging them to anticipate future market trends and customer demands. Firms that are proactive can seize opportunities before competitors and adapt quickly to changes. Additionally, managers can embrace calculated risk-taking by creating a culture where informed risks are seen as a pathway to growth. By carefully assessing potential risks and rewards, firms can pursue ventures with high return potential.

Integrating EO into strategic management can further enhance its impact on performance. Ensuring that the firm's mission, vision, and strategic objectives reflect EO principles can guide decision-making processes that improve competitiveness and performance. Empowering employees to contribute ideas and take ownership of projects is also critical; employees who feel empowered tend to be more engaged, driving innovation and operational efficiency.

EO also offers advantages in leveraging technological advancement. Although AI adoption did not show a direct impact on performance in this study, EO-driven firms are well-positioned to explore and implement AI technologies strategically. Managers can use their entrepreneurial mindset to identify AI applications that align with their innovation goals and may lead to long-term performance benefits.

Exploring selective international opportunities is another approach; applying entrepreneurial capabilities to identify international markets that offer strategic advantages may yield benefits when aligned with the firm's strengths, even though internationalisation did not directly enhance performance in this study.

Continuous improvement and learning are essential components of maintaining EO. Investing in skill development through training programmes that enhance entrepreneurial skills—such as creative thinking, opportunity recognition, and strategic planning—can significantly contribute to performance improvements. Establishing clear performance metrics related to EO initiatives and regularly reviewing these metrics allow managers to adjust strategies as needed to optimise outcomes.

By focusing on these strategies, managers can directly leverage EO to improve performance. Emphasising innovativeness, proactiveness, and risk-taking within the organisation can lead to competitive advantages and improved financial results in the Visegrad chemical sector.

5.3 Guidelines for Policymakers

Policymakers play a crucial role in creating an environment that supports the sustainable growth and competitiveness of SMEs in the Visegrad chemical sector. Based on the study's findings, several recommendations are proposed to support these goals. Given the significant role of Entrepreneurial Orientation (EO) in driving SME performance, AI adoption, and internationalisation, policymakers should implement policies and programs that enhance EO among SMEs. Initiatives such as entrepreneurship training, innovation grants, and support for risk-taking can foster an entrepreneurial culture, better equipping SMEs to innovate and expand into international markets. Policymakers can provide resources and support to help SMEs navigate international regulations, cultural differences, and market entry strategies, aligning with the study's finding that EO positively influences internationalisation. While internationalisation alone does not guarantee immediate performance gains, it can be beneficial in the long term when combined with a strong entrepreneurial foundation.

To enhance the innovation potential of SMEs and leverage EO for performance improvement, policymakers should also consider providing funding and incentives for activities that support AI adoption and technological innovation within SMEs. Although this study did not find a direct link between AI adoption and immediate performance improvements, investing in innovation aligns with EO principles and can build long-term competitive advantages for SMEs. Improving regulatory and economic conditions to encourage entrepreneurial activities and innovation is equally important. Simplifying regulations and reducing bureaucratic barriers can empower SMEs to pursue entrepreneurial initiatives more effectively and with greater agility.

By implementing these recommendations, policymakers can create a supportive environment that enables SMEs to leverage EO, adopt AI technologies effectively, and enhance their performance and competitiveness in the global market.

5.4 Limitation and Directions for Future Research

The current study, while providing valuable insights into the impact of Entrepreneurial Orientation (EO) on AI adoption, internationalisation, and firm performance in SMEs within the Visegrad chemical sector, presents certain limitations that should be acknowledged. One significant limitation is the potential overlap between EO and AI Adoption Orientation, despite efforts to distinguish these concepts. Shared dimensions such as innovativeness and risk propensity could influence the results, potentially conflating the effects of EO and AI Adoption Orientation on SME performance. Rigorous statistical techniques were employed to ensure distinctiveness, yet future research could further explore these relationships using longitudinal data to better understand the causal dynamics. Additionally, the

moderating role of environmental dynamism, as suggested by Dubey et al (2020), could provide deeper insights into how market conditions affect these relationships.

Another limitation concerns the study's geographical and industry focus. Concentrating on a specific region and industry offers a deep, contextual understanding but may limit the generalizability of the findings. While this focus allows for detailed exploration within the Visegrad chemical sector, future research could broaden the scope to include other geographical areas and industries. Such expansion would help in understanding whether the observed relationships hold in different contexts or are unique to the current setting.

The sample size and composition also present limitations. Although the sample size meets the required statistical power, the study's findings are based on a relatively small and specific sample of SMEs. Future studies should aim for larger, more diverse samples to enhance the generalizability and robustness of the findings. Additionally, exploring variations across different sizes and types of SMEs could provide deeper insights into the nuanced impacts of EO on AI adoption and performance.

Furthermore, the research primarily employs a quantitative methodology. While effective in identifying general patterns and correlations, this approach may overlook the rich, qualitative aspects that shape the relationship between EO, AI adoption, internationalisation, and performance. Future research could incorporate qualitative methods, such as case studies or interviews, to capture the complexity and depth of these relationships.

The cross-sectional design of the study provides a snapshot in time, which may not fully capture the dynamic and evolving nature of the theoretical constructs. Longitudinal studies could offer valuable insights into how these relationships develop over time and the long-term impacts of AI adoption on SME performance. Additionally, while the study identifies significant relationships, there is potential to explore mediating and moderating factors that could influence these dynamics. Future research could investigate factors such as organisational culture, leadership, and external environmental conditions to understand their role in the EO-AI-performance nexus.

Finally, the current research focuses on the adoption of AI but does not delve deeply into the specifics of AI implementation and its direct impact on firm processes and outcomes. Subsequent studies could examine the types of AI technologies adopted by SMEs, the challenges and successes in implementation, and the specific impacts on operational efficiency, innovation, and competitive advantage.

In summary, while the study makes significant contributions to our understanding of EO, AI adoption, and firm performance in the Visegrad chemical sector, these limitations highlight opportunities for future research to build on and expand the current findings.

6. Conclusions

This research offers a nuanced understanding of how entrepreneurial orientation (EO), artificial intelligence (AI) adoption, and internationalisation influence the performance of SMEs in the Visegrad chemical sector. The findings highlight that a robust EO significantly boosts performance, AI adoption, and international engagement.

However, the study's geographical and industry-specific focus may limit the generalisability of these findings. Future research should expand into different contexts to validate and extend these observations. Moreover, integrating qualitative methods could deepen understanding of the complex interactions between EO, AI adoption, internationalisation, and performance.

The study also suggests that while AI adoption is on the rise, its direct impact on performance is not immediate, indicating the need for a phased and strategic integration. Similarly, internationalisation presents a varied impact on firm performance, suggesting that mere global expansion is not a panacea for business success; rather, it should be strategically aligned with the firm's EO and AI capabilities.

In conclusion, this research underscores the importance of a dynamic, entrepreneurial approach in leveraging AI and international opportunities. For Visegrad SMEs in the chemical sector, the path forward involves a strategic blend of innovation, risk-taking, and proactive global engagement, underpinned by a robust entrepreneurial orientation.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

VH designed the study, conducted the research, analysed the data, and wrote the manuscript. The author read and approved the final manuscript and is accountable for all aspects of the work.

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Declaration of AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the author used ChatGPT-3.5 to assist with grammar and clarity checks. Af-

ter using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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