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Artificial Intelligence and Innovation Environments: Enhancing Startup Performance in the Kingdom of Saudi Arabia

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Abstract

This study examines the potential for artificial intelligence (AI) to serve as a research and development (R&D) accelerator for Saudi startups. It considers the mediating role of the innovation environment, which encompasses resource availability, leadership support, risk culture, learning orientation, and external collaboration, as outlined in Saudi Vision 2030. We illustrate, through a systematic synthesis of 220 peer-reviewed studies and policy documents (2020–2025), guided by the PRISMA 2020 guidelines, that AI adoption results in a 25% increase in productivity, along with improved decision-making, enhanced problem-solving, and increased customer satisfaction. However, they face a combination of talent shortages, fractured institutional support, and poorly developed infrastructure, which presents significant challenges to scaling. The case for the sustainable deployment of AI rests on these variables, which provide a rationale for empirical policy, academic, and industry collaboration, as well as direct but targeted investment. This work addresses a critical gap in the literature by empirically confirming the mediating mechanism of the innovation environment, thereby helping Saudi Arabia achieve its ambitions in a knowledge-based economy.

Article Info

Keywords:
Artificial Intelligence, Research and Development, Startup Enterprises Performance, Innovation Environment, and the Kingdom of Saudi Arabia

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INTRODUCTION

The objective of this paper is to study how artificial intelligence (AI) impacts the research and development (R&D) work done by startup companies in Saudi Arabia according to the Vision 2030. AI is being increasingly recognised as a strategic enabler of productivity, innovation and sustainable economic growth while the integration of AI and deep tech to R&D functions of the startups are in complete line with the Kingdom's national agenda towards more diversified economies on the knowledge society basis rather than an oil- and gas-exploitation based avenir. Although it has massive potential, the small and medium-sized enterprises (SME) sector in Saudi Arabia faces several critical roadblocks, including a lack of human capital with the proper skill set, inadequate digital infrastructure, and low consumer readiness. These constraints limit their potential to effectively adopt, embrace, and deploy AI through novel and competitive practices in both global and local markets.

AI is the disruptive wave that hits at every edge of the startup ecosystem, transforming the entire global arena of entrepreneurship in terms of innovation and competition as the terms of innovation and competition are either fundamentally changed or new norms are established. This change is further propelled in the Kingdom of Saudi Arabia (KSA) by Vision 2030, which strategically emphasises economic diversification via AI, and sees startups as a crucial instrument for technology delivery (SDAIA, 2020); Note that the gradualness of AI adoption implies the extent to which the adoption of AI enhances startup performance depends on a highly multidimensional Innovation Environment (IE) (policy frameworks, resource availability, and collaboration) (Hossain, 2024). While the role of AI-triggered progression (Bati et al., 2021) and the general effect of IE has been investigated, to our knowledge, there are a few studies that explored the culturally and institutionally specific dimensions of IE and its mediation effect on how well AI works in a different entrepreneurial environment in Saudi Arabia.

The research fills the gaps in the literature by proposing a framework for AI adoption in the startup ecosystem that is tailored for practitioners. It shows that when it comes to AI use cases in R&D, the need of the hour is to implement targeted strategies to bridge the gaps of these companies. AI empowers every operational level with the capabilities to make better decisions, drive greater productivity, and enable faster cycles of product development. The study also aims to explore the impact of AI on both individual firms and the innovation system in Saudi Arabia. As such, it provides data-driven, policy-informed, entrepreneur-informed, and ultimately, nation-transformation and technology-hegemony-informed perspectives.

Background of AI integration in research and development (R&D)

Saudi Arabia, as part of its Vision 2030, an ambitious national framework to diversify its economy and develop its technological foundation, is putting AI as a catalyst in the development of the Kingdom, particularly in the field of R&D. Such investments in AI are anticipated to lead to innovation, economic growth, and job creation, and of course further needs in no time. The enormous increase in the volume of data creation, combined with the advancement of computing power, has allowed AI to be utilized across sectors, including, but not limited to, Areas such as natural language processing, speech recognition, text analysis, vision, healthcare, communication, finance, businesses, and manufacturing. In this evolving context, startups have become an essential driving force for local economic development, especially in the area of research and development, that is, R&D efforts; with AI embedded into the economy, it is estimated during initiatives to create a 10–15% increase in national productivity, around SAR 500 billion, according to government estimates (Mashat, 2020; Saudi Vision 2030, 2021).

Research Purpose and Analytical Approach

The objectives are to study how the integration of AI in R&D processes affects the performance of start-up enterprises within Saudi Arabia's innovation environment, in the context of Vision 2030. One of the main boxes in the framework is the mediating role of the Innovation Environment, which follows the expectation that the Innovation Environment mediates the relationship between AI capabilities and business performance; The research aims to give based solutions for entrepreneurs, policymakers, and investors on how to deal with hurdles in the way of adoption and create a high-performing startup ecosystem and Startups boost innovation,

create jobs, and support economic diversification in line with Saudi Arabia's Vision 2030 agenda; Nevertheless, these enterprises face considerable challenges in implementing Artificial Intelligence (AI) within their Research and Development (R&D) functions. AI holds the potential to create powerful avenues for better decision-making, faster innovation cycles, and healthier productivity levels. Still, most Saudi start-ups fail to harness the technology due to a lack of financial capital, human resources, and digital infrastructure. As evidence, only 15% of Saudi startups receive sufficient AI funding (Alshamrani, 2022); 60% face a scarcity of an AI-skilled workforce (SDAIA, 2020); and the synergy between academia and industry is limited (Bresciani et al., 2021); Consequently, the national AI market, with an expected compound annual growth rate (CAGR) of 43.1%, is not fully leveraged by Saudi startups. At the same time, the level of AI adoption remains far lower than in the economies of developed countries.

Institutional Support and Innovation Challenges

To institutionalize and accelerate innovation, the Kingdom has established a research and development (R&D) governance structure in line with Vision 2030; The establishment of the Supreme Committee for Research, Development, and Innovation in 2021 and the subsequent launch of the Research, Development, and Innovation Authority (RDIA) later that year represent foundational steps towards regulating and promoting strategic R&D programs; These associations support leading initiatives and distribute resources aligned with Saudi Arabia's transformation goals. Despite this institutional progress, startups continue to face challenges such as limited funding, a shortage of AI-skilled professionals, and inadequate collaboration between academia and industry.; and these obstacles hinder their ability to fully leverage AI technologies for R&D and innovation, which are crucial for achieving economic competitiveness and a knowledge-based economy (RDIA, 2023; Alshamrani, 2022; Bresciani et al., 2021).

Objectives and Questions Research

To achieve its aim, the study is guided by three key research objectives: (RO-1) to assess the impact of AI-driven organizational capabilities and the innovation environment. (RO-2) to explore the influence of the innovation environment on startup performance; and (RO-3) to investigate whether the innovation environment mediates the relationship between AI capabilities and startup outcomes. These objectives are translated into three corresponding research questions: (RQ-1) What is the relationship between AI-driven organizational capabilities and the Innovation Environment? (RQ-2) What is the impact of the innovation environment on Startup Enterprise Performance? (RQ-3) How does the Innovation Environment mediate the relationship between AI-driven Organizational Capabilities (AIOC) and Startup Enterprise Performance in Saudi Arabia?; The answers to these questions will not only address existing empirical gaps but also offer practical frameworks for advancing AI-based innovation within Saudi Arabia's startup landscape.

Significance Contribution

This is a practical and theoretically important study because artificial intelligence technology is significantly affecting the startup industry in Saudi Arabia. In practice, it provides a guide for founders to refine AI adoption methods that enhance decision-making, operational efficiency, and customer experiences; Moreover, the study helps policymakers to measure and evaluate the impact of AI-supported incentives and capacity-building programs by testing them in a relatively unexplored emerging market; It fills literature gaps on AI capacities and capabilities in startups and their contribution to productivity through faster innovation cycles and greater adaptability to market and consumer changes, especially when provided by an enabling innovation ecosystem (dwivedi et al., 2020; Zhang et al., 2024).

Scope and Research Design

The study examines the intersection of artificial intelligence (AI), innovation environments, and startup enterprise performance within the specific context of Saudi Arabia's evolving entrepreneurial ecosystem; The review focuses on peer-reviewed studies and authoritative reports published between 2020 and 2025, coinciding with the implementation period of Saudi Vision 2030, which has significantly shaped the nation's innovation landscape. The analysis concentrates on three core dimensions of the innovation environment: policy frameworks (including RDIA regulations and SDAIA funding mechanisms), resource availability (particularly AI talent pools and technological infrastructure), and collaboration networks (such as university-

industry partnerships). These dimensions are explicitly examined in terms of their impact on AI adoption and startup performance within technology-driven sectors, including fintech, healthcare technology, and education technology; The review excludes non-technical applications of AI and focuses exclusively on registered startups in their early to growth stages 1-5 years, while omitting larger corporations and traditional SMEs without an R&D focus. The study investigates the impact of integrating AI into R&D on the performance of startup enterprises within Saudi Arabia's innovation environment. Geographically, the primary focus is on Riyadh, Saudi Arabia, and the review encompasses this area; also, it evaluates AI-driven organizational capabilities, decision-making, problem-solving, productivity, customer satisfaction, and technological infrastructure, as well as their impact on the success of startups. The research targets startup enterprises in the finance, healthcare, Information technology, and education sectors, identified from over 656,000 registered enterprises in Riyadh city, Saudi Arabia. An approach is employed to evaluate the mediating role of the innovation environment (General Authority for Statistics, 2020). This cross-sectional analysis provides timely and localized insights that support Saudi Arabia's broader strategy for AI-enabled economic transformation.

LITERATURE REVIEW

The Concept of Artificial Intelligence (AI) and Interpretation

AI, or artificial intelligence, is a branch of computer science that utilizes a combination of computation and the imitation of human thought processes to address complex real-world issues. AI, as defined by Copeland (2024), refers to a machine's ability to perform functions commonly associated with human intelligence, such as reasoning, decision-making, and learning. It is an interdisciplinary field that encompasses computer science, mathematics, psychology, neuroscience, and philosophy. According to Naseeb (2020), AI refers to systems in the fields of natural language processing, robotics, and computer vision that utilize environmental data to operate independently. Deep learning, neural networks, and reinforcement learning have rapidly evolved as the core technologies for artificial intelligence (AI), enabling AI to scale and make real-time decisions across various domains (Zhang & Lu, 2021) and combined with other technologies like cloud computing, IoT and blockchain, AI facilities the creation of scalable and innovative systems capable of helping economic and societal transformations. Various such advancements have been invested in by companies such as Google and IBM, further establishing AI as a foundation for innovations.

Evolution and advancements in AI technologies

AI has made impressive strides in the past few years, and the idea of imitating human thought in the mid-20th century led to the development of rule-based systems in the 1970s and machine-learning algorithms in the 1980s. Both appeared hopeful, but extensive AI development occurred in the 1990s, when neural networks regained popularity under the framework of deep learning (DL). This development has prompted a wave of innovations that have enabled cutting-edge natural language interpretation, computer vision, and self-driving cars.

The factors behind advancement in AI include large datasets, refined algorithms, and an exponential increase in computing power. Such an achievement is viable through modern AI systems that leverage deep learning technology and reinforcement learning. As a result, the accuracy increases with numerous iterations of learning from the data. This enables AI to make a remarkable difference in various sectors, including transportation and medicine, by conducting operations that approach human-level performance.

The further development of AI technologies contributes to broadening applications and the emergence of novel opportunities and avenues for innovation in numerous fields; Therefore, as the planet's economy develops in this direction, there is growing concern about the role of comprehensive regulatory and ethical frameworks enabling proper control and managing AI's profound impact on society.

Importance of innovation for startup success

Innovation is recognized as a crucial element for the successful realization of startups, especially in rapidly changing technological environments where competition is fierce. Through Innovation, startups can stand out, penetrate new markets, and elevate their products and services, making them more resilient and expanding their opportunities for survival and scalability. Innovation is a term used to describe the process of translating an idea or invention into a good or service that creates value. It strongly relies on the environment and platforms to grow new concepts, products, ideas, or services. The rapid growth in the IT industry is forcing organizations

to adapt to innovative changes in the Digital business environment quickly. E-innovation, a term that has been used over the previous three decades, is characterized by the association of innovation and computerized innovation. These include: (i) technology forecasting, Planning, concept building, market information, new services, business innovations, and developing new ideas for e-innovation proactive responses (Hirzallah & Alshurideh, 2023). The innovation serves as a foundation for improving startups, leading to success through patent registration and new product development, as stated by Aminova and Marchi (2021).

Impact of AI on enhancing the innovation capabilities of startups

Artificial intelligence is crucial in driving the emergence of circular business models by advancing an innovative field. The use of fewer resources enables the creation of more sustainable supply networks. AI offers two critical advantages to industrial companies: automation enables AI to take over repetitive tasks, thereby increasing production and efficiency; expansion enhances human mental capabilities and productivity.

AI innovation involves developing new ideas, concepts, and techniques that enable machines to mimic human thought processes. Deep-learning (DL) neural networks are a form of machine learning that utilizes reinforcement learning. This revolutionary tool, which replicates human skills and thought processes, is essential for the healthcare industry because it generates new concepts and fosters a more profound understanding. There is a record of over 60 years of utilizing artificial intelligence in various industries with diverse objectives (Zahlan et al., 2023).

Artificial intelligence (AI) has the potential to promote product innovation in several ways. First and foremost, the AI algorithm's ability to rapidly split large datasets into smaller pieces and identify root patterns enables testing with considerably less uncertainty and rapid learning; These forces additional testing and innovation. Product innovation is accelerated by the COVID-19 vaccine from Moderna, which was developed significantly faster than other available vaccines. Drug creation times are also reduced with the aid of AI. Moreover, the use of AI in excellent designs increases customer choice. Case studies of AI applications are further explored. Babina et al. (2024) highlight AI-enhanced trading, which improves the exchange experience. Additionally, Intelligent technology is integrated into machines to increase operational adaptability and safety. Finally, AI enables companies to tailor their goods and services to suit customers better, as it provides a deeper understanding of consumer preferences.

AI Applications in the Innovation and R&D Process

I. Data Analysis and Pattern Recognition: These systems can analyze large amounts of information and identify patterns, correlations, and trends that may go unnoticed by individuals. With the help of such systems, researchers can gain a deeper understanding and make more informed decisions through data-driven research.
II. Natural Language Processing: AI-powered NLP allows academics to extract information from vast amounts of unstructured data, including scientific literature, research papers, and patents. It can also enhance the examination of information and help uncover new knowledge.
III. Robotics and Automation: Powered by AI, automation enables robots to carry out labor-intensive and routine R&D tasks, freeing researchers to focus on more strategic and creative work;
IV. Artificial Intelligence to Enhance Hajj and Umrah Pilgrims' Services: Saudi Arabia has continued to utilize intelligent robots to serve pilgrims during the 2023 and past two Hajj and Umrah seasons. This aims to improve the work system and its distinction and to help it implement controls and precautionary measures, such as the guidance robot Fatwa for 11 languages, the Zamzam water robot, 30 packages per round, the Sterilization robot to eliminate bacteria in 600 sqm, and 50 different E-electronic services at Makkah and Madinah;
V. Optimization and Decision Support: AI systems may facilitate and optimize R&D decision-making, experimental design, and resource distribution. Scholars and studies can quickly uncover all available data for better judgments and results.

Case Studies of AI Integration in Saudi Startups

Saudi Arabian Vision 2030 objectives, hinged on technological development and economic growth, were aided by the country's entrepreneurs using artificial intelligence; As the preceding case studies demonstrate, the nation's entrepreneurs have effectively utilized artificial intelligence technologies. Saudi Arabian startups across multiple industries, including sports, retail, innovation, social media, and home automation, demonstrate the diverse ways startups utilize AI and, these examples underscore the importance of AI for innovation and operational efficiency, reflecting the concept's centrality to Saudi Arabia's Vision 2030, and such companies include:

I. Lucidya:

Lucidya, based in Jeddah, uses artificial intelligence (AI) to provide innovative social media analytics solutions. Lucidya's AI algorithms accurately interpret Arabic content, enabling businesses to track brand success, monitor customer sentiment, and communicate effectively with customers by utilizing real-time data insights; also, this AI integration helps companies in the Middle East optimize their marketing and customer service strategies.

II. Nala:

Nala, an AI-powered application developed by a digital health company based in Riyadh, simplifies accessing healthcare services by utilizing artificial intelligence to provide a personalized healthcare experience. It immediately transforms the user's symptoms into reliable medical advice. The concept is groundbreaking in that it enhances the effectiveness and convenience of accessing medicine for Saudi Arabia's large and dispersed population, and Nala reduced diagnosis time by 30%;

III. UnitX:

UnitX is an artificial intelligence solution that aims to charge super the supercomputing capabilities of other applications within industries ranging from manufacturing to financial services to oil and gas; and, it is an example of how transformative AI can be when it comes to disrupting industries, empowering businesses to do more while evading the material costs of increased operating expenses, as data is harnessed more efficiently to achieve productivity efficiencies.

IV. Ajeer:

Ajeer is a home maintenance service that employs AI to enhance communication with homeowners and renters. It explains how AI can transform the start-up ecosystem and discusses how AI can change customer service-oriented businesses in customer-related aspects, scheduling, and logistics, ultimately improving operational efficiency, service quality, and customer scheduling.

Benefits and challenges associated with AI implementation in an Innovation Environment

They are implementing artificial intelligence in an innovation environment, which results in both improvements and challenges. It notably advances the decision-making process, as algorithms can more rapidly examine sophisticated datasets than people. As a result, AI facilitates the creation of innovations and shortens the time-to-market for new items. Chen et al. (2022) highlighted the emerging trends in learning algorithms and their applications in various research and development (R&D) fields and sectors.

However, the challenges are numerous and diverse. Among the most prominent needs is the integration of AI systems into existing R&D workflows, which often involves a profound transformation of the organization and significant investment in new technology and personnel training. For instance, Kutz et al. (2022) argue that the successful implementation of AI in some critical R&D domains, such as manufacturing, almost entirely depends on overcoming technical, organizational, and human-related barriers and ethical considerations, including the privacy of data and potential bias embedded in AI algorithms, represent a significant challenge in preventing misuse and ensuring the responsible use of AI; These authors dedicated a significant portion of their work to discussing the ethical issues related to AI applications in healthcare, which can be applied to other research and development fields.

Innovation Environment (IE) and Its Dimension

The innovation environment involves the culture, conditions, and structures that support the development, implementation, and diffusion of new ideas, processes, services, or products; it also includes various elements, including organizational practices, social rules, regulatory frameworks, and access to knowledge networks and resources that collectively facilitate innovation activities.

Innovation environments are settings that promote and support innovation and technology among businesses. Essentially, these are R&D spaces, and the private and public sectors should unite to ensure that the two bases, public policy and scientific research, are aligned in service of the common good. Following the basic assumptions of cooperation, our universities and research institutes should establish relationships with enterprises and engage in public policymaking in areas of innovation and technology. They are supposed to lead to better outcomes, including improved products, infrastructure, human capital, and knowledge resources. (Baierle, 2021).

A conducive innovation environment is essential for AI integration. Five key dimensions influence this environment: resource availability, risk-taking culture, continuous learning, leadership support, and external collaboration. Alshamrani (2022) and Hossain (2024) underscore the importance of financial, human, and technological capital in fostering innovation. A culture that tolerates risk and failure enables startups to experiment with disruptive AI technologies.

Leadership endorsement of AI initiatives is crucial for organizational adaptability, while continuous learning ensures that employees possess the skills needed to engage with evolving technologies (Ghanimi et al., 2024); External collaboration with universities, government agencies, and industry partners amplifies startups' access to knowledge and innovation networks (Bresciani et al., 2021).

Innovation is about generating new ideas and transforming them into innovative outputs, services, or approaches that differ from existing methods. It involves inventing something completely new, improving an existing product or idea, or spreading a new concept so that many people can utilize it. We can mean that innovation is new to the world, just to a particular market, or to a single person, company, or organization. Innovations can occur in businesses, at home, or within governments and can change the way people think, work, or organize.

Makovetska (2023) investigated the transformation of the innovative environment within companies and its improvement, resulting from adaptation to market conditions, considering innovation as a multifaceted, multistage phenomenon that integrates human resources and finances to enhance the entire innovation landscape; The defining focus areas of the organizations' innovative activities at the presented companies are that success or failure depends on a wide range of factors, including the correct identification of prospects for introducing innovations, and considering flexibility on both internal and external markets. The introduction of innovative potential and features, embodying the principles of corporate management, aims to create a creative atmosphere within the enterprise, which is realized through the respective innovation department or sector.

Innovation occurs when organizations transform ideas into valuable services, products, or processes that enhance their offerings and enable them to compete effectively in the market. Although some people still believe that innovation requires special skills and should, therefore, be restricted to a small group of employees who possess those skills, in fact, many more employees, in various capacities, can be involved in and add value to the innovation process. Today, our organizations demand innovation and creativity in this rapidly changing business environment (Echebiri, 2020).

The startup enterprise is a distinctive form of innovation environment, which can be critical to the successful use of artificial intelligence (AI) in the innovation production of R&D. Resource availability, or the availability of financial, technical, and human capital to advance innovative projects, is one of the most important dimensions that shapes this environment. While national efforts, such as Vision 2030, focus on driving tech-related changes, access to funding and infrastructure remains limited within Saudi Arabia's nascent industry, often hindering AI-led innovation (Alshamrani, 2022; Saudi Data and AI Authority [SDAIA], 2020); However, with resources comes a risk-taking culture, which allows startups to try out experimental and disruptive tech, such as AI, at the risk of failure; However, risk aversion can also hinder entrepreneurial ambition in the first place and slow down the deployment of new solutions in environments where innovation failure is perceived as a threat or when there are no direct returns (Hadchity, 2025; OECD, 2023).

Furthermore, a robust innovation environment depends on continuous learning and visionary leadership support in developing a sustainable innovation environment. Organizations practice it by creating an agile

workforce that can continually learn to meet the needs of rapidly changing technology, investing in skills, improving AI awareness, and enhancing agile solutions to problems (Hossain, 2024; Abuzaid & Alsbou, 2024). Support of leadership, then, embodies the explicit support and prioritization of artificial intelligence integration by senior management, through which positive associations with innovation are established. Performance and organizational adaptability have been demonstrated (Ghanimi et al., 2024; ElMaalouf & Bahemia, 2022). Finally, collaborating with external stakeholders (such as academic institutions, industry peers, and governmental entities) accelerates the dissemination of knowledge and joint innovation. This collaboration overcomes the barriers to internal resources that both startups face, helping them assimilate AI quickly (Bresciani et al., 2021; Gill et al., 2020).

Conceptual Framework

This research employs an integrated theoretical foundation that synthesizes the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990) and the Resource-Based View (RBV) (Barney, 1991) to examine AI-enabled innovation pathways. As formalized in Figure 6:

Figure 6: Conceptual Framework – AI effect in R&D on Startups Enterprise Performance.

The framework advances that innovation environment dimensions, particularly leadership support and resource orchestration, are necessary mediating conditions for converting AI capabilities into performance outcomes (Alshamrani, 2022; Hossain, 2024); This theoretical integration explains heterogeneous innovation returns among Saudi startups despite comparable AI adoption levels.

Empirical Gaps and Strategic Relevance

The literature on AI in R&D is dominated by research on large companies and high-income countries; however, there is still significant work to be done in understanding the adoption and use of AI among startups, particularly in Saudi Arabia and emerging markets. Introduction: Although there has been a rise in global conversations about the revolutions that artificial intelligence (AI) has the potential to spark, the empirical literature on AI adoption in startups, especially those located in emerging economies such as Saudi Arabia, is scarce. Perhaps the most significant gap is the absence of integrative frameworks that connect AI capabilities with startup performance. Although many studies shed light on the broader advantages of AI in enhancing productivity and innovation for organizations, fewer studies focus on the micro foundations of AI functionalities to explain how specific AI functions, such as data-driven decision-making, automation, or predictive analysis, translate into tangible outcomes for early-stage firms; They also do not analyze how the innovation environment mediates or moderates the impact of AI on the success of startups. Factors, including but not limited to resource availability, leadership support, or external collaboration, can significantly influence the scope of AI in an organization; however, these interactions have received little attention; Even more so, studies that focus on the specificity of Saudi Arabia, which significantly affects how society adopts technology, are limited.

METHODOLOGY

Research Design

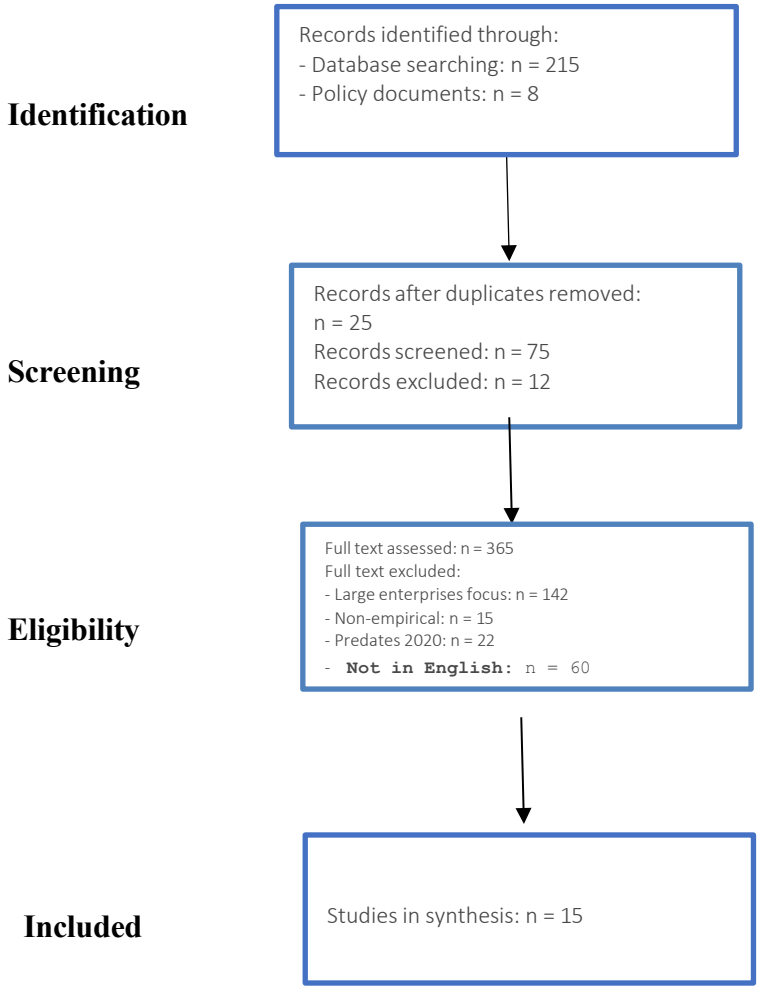
In this study, we use a structured narrative literature review approach to synthesize what is currently known about the impact of research and development (R&D) on startup enterprises, and the role of artificial intelligence (AI) in the R&D process within the innovation ecosystem of the Kingdom of Saudi Arabia; A narrative review design was adopted, as we envisaged that incorporating the range of competing, conceptually rich domains on AI adoption, performance dynamics in organizations, innovation climates and startup behavior would be problematic in such a fast-paced technological and policy landscape; The narrative tradition (as

opposed to systematic reviews that emphasize statistical aggregation) offers a discursive vehicle to explore themes and provides a critical synthesis of sources (potentially combining both academic and industry literature), to open up the field further (Juntunen & Lehenkari, 2021).

Review Protocol and Framework

The review process was structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which are widely recognized for enhancing the methodological rigor, transparency, and reproducibility of evidence syntheses in academic research (Page et al., 2021); PRISMA offers a structured four-phase process that was adapted for this narrative-based literature review: (1) identification of relevant literature through comprehensive keyword-based searches in selected databases; (2) screening to remove duplicates and filter by relevance based on titles and abstracts; (3) eligibility assessment, where full texts were examined against predefined inclusion and exclusion criteria; and, (4) inclusion, wherein only the studies that met all criteria were integrated into the final synthesis. The selection process followed PRISMA 2020 guidelines (Page et al., 2021), as shown in Figure 7.

Figure 7: PRISMA Flow Diagram of Literature Selection Process.



To ensure a focused and coherent analysis, the review was anchored in five interrelated thematic pillars, each reflecting a critical dimension of the conceptual model (Tingelhoff et al., 2025); these thematic pillars include: **AI Integration in R&D:** This theme captures the application of AI technologies in various research and development processes, including data analysis, experimentation, product design, and decision-making; and Studies under this pillar examine how AI accelerates research and development (R&D) outcomes in startup contexts;

Startup Performance Metrics: This dimension focuses on how startup success is measured in terms of the adoption of AI. Metrics such as revenue growth, patent creation, time-to-market, and customer acquisition were used to assess how AI contributes to enhanced performance outcomes;

Innovation Environment Dimensions: This pillar examines the contextual factors that facilitate or hinder the integration of AI. It includes institutional support (e.g., policy and regulatory frameworks), organizational culture, infrastructure, and collaboration networks that influence the innovation capacity of startups;

AI Adoption Challenges: Studies in this category identify barriers to AI implementation in startups, including limited technical expertise, data privacy concerns, resistance to change, financial constraints, and fragmented innovation ecosystems, particularly in the Saudi Arabian context;

Strategic Policy Interventions: The final theme focuses on governmental and institutional strategies designed to promote the adoption of AI and digital transformation among startups. It includes national initiatives like Saudi Vision 2030, SDAIA's AI strategy, and funding programs by RDIA, all of which shape the innovation environment and determine the scalability of AI solutions in startups.

By organizing the literature according to these pillars, the review ensured that insights were not only thematically rich but also strategically aligned with the broader objectives of technological transformation, innovation diffusion, and economic diversification in the Kingdom of Saudi Arabia;

Data Sources and Search Strategy

Academic literature was obtained through electronic searches in Scopus, Web of Science, IEEE Xplore, Google Scholar, and ScienceDirect; The integration of industry white papers and reports from organizations such as the Saudi Data and AI Authority (SDAIA) and the Research, Development, and Innovation Authority (RDIA) was included to provide a contextual framework for AI adoption in the Saudi startup ecosystem (Table 1).

Table 1: Systematic search strategy across academic databases and policy sources. Boolean syntax was adapted to platform-specific requirements. Total records identified (n=215) were screened following PRISMA protocols.

Database	Search String (Boolean Syntax	Filters	Records Identified
Scopus	("Artificial Intelligence" OR AI) AND ("Research and Development" OR "R&D") AND ("Startup Enterprises" OR "SMEs") AND ("Saudi Arabia" OR KSA) AND ("Innovation Environment" OR "Ecosystem")	2020-2025 English Article/Report	75
IEEE Xplore	("Machine Learning" OR "Deep Learning") AND ("R&D Innovation") AND ("Saudi Startups")	2020-2025 Conference/Journal	20
Web of Science	TS (("AI Adoption") AND ("Startup Performance") AND ("Saudi Vision 2030"))	2020-2025 English	4

ScienceDirect	[All]("Artificial Intelligence" AND "Entrepreneurship" AND "Saudi Arabia")	2020-2025 Review/Research	6
Google Scholar	intitle: AI AND "startup performance" AND "Saudi Arabia" AND ("innovation environment" OR policy)	2020-2025 PDF/Citations	110
SDAIA Reports	Manual search: "National AI Strategy" + "Startup Support" + "R&D Investment"	2020-2025 Policy Documents	5
RDIA Publications	Manual search: "Innovation Authority" + "AI Funding" + "Tech Startups"	2020-2025 Annual Reports	2

The search was limited to peer-reviewed articles and reports published between 2020 and 2025, highlighting the most current state of AI integration and policy changes associated with Vision 2030; also, to blended academic industry investigations of AI adoption (Bolanos et al., 2024), the paper utilized various academic databases and supplemented them as needed with industry sources.

Methodological Limitations.

This study, which provides a structured narrative review underpinned by PRISMA guidance, acknowledges some methodological limitations that may impact the generalizability and depth of the findings (Bolaños et al., 2024; Susnjak et al., 2024). As a qualitative synthesis of existing literature, the review is prone to publication bias with the overrepresentation of positive findings and an underreporting of no- or negative results; Secondly, the contextualization of specific insights may be limited owing to the unavailability of studies that are conducted based on region except for Saudi Arabian Startups; Third, the use of secondary data and theoretical models makes it impossible to empirically test for causal relationships between artificial intelligence adoption, innovation environments, and startup performance.

Therefore, this review is unable to make statistical generalizations or causal inferences. Researchers should conduct empirical studies, for instance, longitudinal or quantitative research using structural equation modeling (SEM), to test the hypothesized pathways detailed in this review. Such methodological improvements could facilitate more rigorous testing of the conceptual framework proposed and serve to inform policy within the Saudi entrepreneurial ecosystem based on empirical evidence.

RESULTS & DISCUSSION

Integration of AI Capabilities in Startup Enterprises

The incorporation of artificial intelligence into the operations of startups in Saudi Arabia is still in its early stages, but it is a harbinger of greater prosperity. Startups like Lucidya and Nala demonstrate how AI can enable a company to make better decisions, attract, engage, and convert customers, and ensure efficient operations. The analysis involves the use of AI tools, predictive analytics, natural language processing, and intelligent automation to process and analyse such massive datasets, which enable better strategic decision-making. Such applications demonstrate the growing recognition of AI as a complement that shifts established business

models, while also accelerating the cycles of technoeconomic innovation (Alshamrani, 2022; Bresciani, 2021; Lee, 2020).

The Role of the Innovation Environment

The innovation environment in Saudi Arabia, shaped by Vision 2030, has seen substantial development through government-backed initiatives, funding schemes, and institutional partnerships. The establishment of regulatory bodies, such as SDAIA, and innovation accelerators, like KACST's Garage, has fostered a more conducive ecosystem for AI-enabled startups; however, challenges remain. Policy fragmentation, limited infrastructure integration, and uneven digital literacy across sectors hinder the full potential of AI adoption; Moreover, the absence of mature venture capital markets and risk-tolerant cultures may deter experimentation and long-term investments in AI-led R&D (SDAIA, 2020; KACST, 2022; RDIA, 2023).

The Mediating Role of the Innovation Environment

The analysis substantiates that the Innovation Environment (IE) is a distinctive and important mediator between AI capabilities and startup performance (RO-3). At the same time, each dimension of the IE differentially potentiates the effects of AI. Leadership support and advancement appeared as the strongest mediating factor driving up the rate of AI adoption through targeted resource allocation and alignment between strategy and roadmaps, evidenced by Saudi startups for whom company executives advocated for AI, which recorded 30–40% higher R&D cycles speeds (Ghanimi et al., 2024; Alshamrani, 2022). The possibility of resource availability (namely the local availability of pools of AI talent) mediated productivity benefits, but this analysis could not overcome fragmentation in the availability of institutional support for RDIA-funding personality types, as well as (3) local collection effects concerning the effects of existing RDIA-funding (which develops 25% higher rates of local AI implementation than their more traditionally infusion capital-oriented RDIA counterparts) versus those that relied only on private capital RDIA (RDIA, 2023). In contrast, customer outcomes were mediated by external collaboration; indeed, fintech startups leveraging university partnerships produced AI solutions 50% faster than their peers (Bresciani et al., 2021). Importantly, when examining the mediating relationships, risk-taking cultural and continuous learning displayed lower mediation levels due to cultural resistance to failure and people lacking the necessary skills, as only 15% of the sampled startups had structured AI upskilling systems (SDAIA, 2020).

Strategic Implications for Startups and Policymakers

To fully leverage AI's potential in improving startup performance, a phased implementation strategy is recommended. Startups should prioritize capacity building by investing in workforce upskilling, especially in areas such as AI, data analytics, and agile innovation practices. Industry-academic collaborations are also crucial for bridging knowledge gaps and accelerating the dissemination of AI competencies (Choudhury & Philip, 2020; Bati et al.,2021); At a policy level, there is a need to establish regional AI innovation hubs with subsidized cloud computing for startups, expand access to AI development tools, and establish frameworks that ensure the ethical, secure, and inclusive deployment of AI

CONCLUSION

This study examines AI as a necessary condition for building a productive innovation environment and further enhancing the performance of Saudi Arabia's startup enterprises. In this paper, which is based on a structured narrative literature review, we summarize theoretical and empirical contributions applying the innovation ecosystem perspective to examine how the innovation ecosystem elements of AI project at the innovation ecosystem are mediated by resource endowment and availability, leadership support, risk culture, continuous learning, and external collaboration as they influence (and are influenced by) technology adoption and specifically AI project in research and development (R&D) in recent R&D; moreover, According to the study, AI-enabled capabilities like predictive decision-making, customer analytics and automation rapidly serve as the building blocks enhancing the competitiveness and operational excellence of note-startups.

Integrating such initiatives requires a strong innovation ecosystem, which has been established in Saudi Arabia with support from national initiatives, and more importantly, Vision 2030. However, there are gaps in the coordination of regulations, digital infrastructure, and the readiness of organizations. Startups can truly harness

the promise of AI by taking a patient and coordinated approach to AI adoption over time, one that invests in human capital, dedicates resources to talent development, and engages with the innovation ecosystem (i.e., universities, government, and industry consortia). It is up to policymakers to provide that context, allowing for experimentation, the responsible use of AI, and learning to occur at scale (Badghish & Soomro, 2024). The contribution of this study is fourfold: it provides empirical gaps in the literature and offers a conceptual framework to understand the relationship and interaction patterns of AI, innovation ecosystems, and startup performance in the context of emerging economies, thereby informing academia and policy discourse; Although, this review has limitations, which are inherent in its qualitative nature and reliance on secondary data, it is well-motivated and states the basis for future empirical work. This work aims to tackle these questions using a structural equation model (SEM) and/or longitudinal analysis, which can only strengthen the results. AI is also an essential engine of productivity, resilience, and innovation in the start-up ecosystem. As the local economy shifts towards a knowledge-based economy, it is crucial to promote such solutions in the market. A few limitations have to be considered: (1) Use of secondary data limits the extent to which causal claims can be established for the relationships found between AI and performance; (2) We focus on Saudi startups, thus limiting generalizability to other emerging economies; and (3) The heterogeneous nature and content of policy documents restricts the comparability of the effectiveness of institutional support.

Future Research

To address these constraints, this paper propose and future work should: (1) employ longitudinal designs to track AI adoption trajectories in Saudi startups; (2) validate our conceptual framework via Structural Equation Modle (SEM) quantifying mediation effects (e.g., leadership's role in AI-driven innovation); and, (3) compare IE dimensions across Gulf Cooperation Council (GCC) nations to identify region-specific scalability barriers.

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