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Fostering Innovation and Startups in Indian Universities: A Hierarchical Analysis

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Abstract

This study investigates the structural dynamics of the startup ecosystem within Indian universities by employing Interpretative Structural Modeling (ISM) to identify and organize the critical enablers of innovation and entrepreneurship. Amid rising interest in university-driven innovation, the Indian context demands a nuanced understanding due to its socio-economic and institutional diversity. Through expert consultations and systematic modeling, this research reveals a hierarchical framework wherein incubation emerges as the foundational driver, followed by pivotal elements such as mentorship, networking, leadership, and funding. Academic regulations are positioned at the apex, indicating their overarching influence on shaping innovation behavior and institutional priorities. The study further explores how leadership integrates various components, and how cultural, educational, and regulatory factors interact to either support or constrain innovation. Regional disparities in innovation ecosystems are highlighted, with evidence showing variations in entrepreneurial attitudes and support structures across Indian states such as Karnataka, Gujarat, and Punjab. The discussion outlines actionable strategies for universities, policymakers, and industry stakeholders to translate these findings into measurable outcomes. Indicators such as patents filed, startups launched, and funding attracted are suggested as benchmarks for innovation success. By presenting a structured, scalable model, the study provides valuable insights for designing inclusive, resilient, and performance-driven university innovation ecosystems across India.

Keywords: Education, Entrepreneurial Orientation, Funding, Incubation, Network.

Introduction

Entrepreneurship, a key driver of economic growth and innovation, has garnered significant global attention. Initiatives like the World Bank's Doing Business project, launched in 2002, have played a crucial role in shaping global business environments by emphasizing the need for supportive ecosystems for small and medium enterprises (1). Similarly, the Global Entrepreneurship Index (GEI) 2020 provides valuable insights into how countries foster entrepreneurial activities, particularly with a focus on innovation (2). These frameworks underscore the complex interplay of local and international factors in determining entrepreneurial success. India's entrepreneurial landscape reflects both challenges and opportunities (3). Despite significant obstacles, the country has demonstrated its capabilities in process innovation (4) and entrepreneurial growth (5). Reforms aimed at simplifying business procedures and improving trade infrastructure have significantly enhanced India's global entrepreneurial standing. However, fluctuations in India's GEI rankings highlight the need for a more consistent and supportive ecosystem to nurture and sustain entrepreneurial ventures. Globally, universities are recognized as critical incubators for innovation and entrepreneurship (6). Prominent examples such as Silicon Valley's origins in Stanford University and the UK's Cambridge Cluster illustrate the transformative role universities play in fostering entrepreneurship and driving national economic development. In India, a deliberate shift toward integrating entrepreneurial thinking into academic frameworks is evident (7). Initiatives such as the Atal Innovation Mission and the establishment of incubation centers at premier institutions like the Indian Institutes of Technology (IITs) and Indian Institutes of Management (IIMs) reflect this trend (8). However, a systematic

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evaluation of the effectiveness of these initiatives and the overall health of the university startup ecosystem remains essential. This paper is systematically structured to provide an in-depth analysis of the startup ecosystem within Indian universities, employing Interpretative Structural Modelling (ISM) as the primary methodology. The paper begins with an introduction that contextualizes the significance of entrepreneurship globally and in India, followed by a comprehensive literature review that explores existing research on critical domains such as extracurricular activities, networking, and funding. The methodology section elaborates on the ISM approach, including the construction of a Self-Structured Interaction Matrix (SSIM) and transitivity analysis. The results section presents the ISM findings, elucidating the hierarchical relationships within the ecosystem. Subsequently, the discussion integrates these findings with the existing literature to offer deeper insights and implications. The paper concludes with a summary of key findings, reflecting on the study's contributions and offering recommendations for policy, educational reform, and future research. The overarching goal of this study is to provide a nuanced understanding of the university startup ecosystem in India, offering actionable perspectives for educators, policymakers, and researchers in the field of entrepreneurship.

Extracurricular Activities (Ecas)

Extracurricular activities (ECAs) play a crucial role in shaping entrepreneurial ecosystems within universities, as evidenced by a range of scholarly investigations. The integration of ECAs with business curricula and entrepreneurship education has been highlighted as a key factor in enhancing student startup success and entrepreneurial competencies (9). However, some studies reveal a paradox where ECAs might unexpectedly impede entrepreneurial initiative, while also emphasizing their role in developing social entrepreneurial leadership within Middle Eastern universities in sanction-free educational environments (10). Additionally, the need for inclusivity in entrepreneurial ECAs has been pointed out, highlighting the importance of considering diverse student backgrounds (11). A pedagogical shift towards industry alignment in business education has been proposed (12), a sentiment echoed in the evaluation of the Hilaris Business Class Program, which advocates for closer ties between education and entrepreneurial practice (13). Further studies explore the impact of ECAs on entrepreneurial learning and intentions, emphasizing the role of self-efficacy and the necessity for diverse activities to cultivate entrepreneurial mindsets (10).

Networking

Networking plays a crucial role in the development of entrepreneurial ecosystems within universities, a theme explored across various global contexts. Research highlights the significance of both internal and external contacts in fostering entrepreneurial success in Jordan and the influence of elite institutions in Brazil in shaping entrepreneurial networks, potentially affecting regional equality (14). Universities are emphasized as key facilitators of venture creation through activities that enhance social networks (15). Startups are found to collaborate with a diverse range of actors, illustrating the critical role of networks in their sustainability (16).

Additionally, personal experience and social networking, particularly among peer groups, families, and educational institutions, are identified as pivotal factors in shaping entrepreneurial intentions (15). Entrepreneurial networks are conceptualized as inherently collaborative (17), with meta-analytic studies demonstrating the influence of network properties on entrepreneurial growth (18). Furthermore, the development of context-specific networking strategies and the efficient utilization of networks are advocated to support entrepreneurial ecosystems effectively (19). Lastly, entrepreneurial education that fosters network ties, innovativeness, and proactiveness is identified as a fundamental enabler of vibrant academic entrepreneurial environments (20).

Entrepreneurial Culture

The role of entrepreneurial culture in fostering startup ecosystems within universities is a multifaceted theme explored across various studies. Research highlights the critical role of entrepreneurial leadership in organizational cultures, particularly in enhancing innovation and mentorship in Pakistani firms (21). This is extended to higher education, where leadership within a UK university demonstrates how aligning staff with entrepreneurial attributes is essential for cultivating an institution-wide entrepreneurial

culture (22). The importance of entrepreneurial management culture in large organizations provides insights into successful cultural interventions (23).

Entrepreneurial culture in academic institutions is argued to be a necessity for economic gains, with variations in entrepreneurship outcomes attributed to differences in such cultures (24). Similarly, project-oriented work in universities is identified as significant in fostering students' entrepreneurial culture (20). Frameworks for entrepreneurship education and technology commercialization have also been proposed (21), while the impact of higher education structures on students' entrepreneurial intentions has been investigated (15). Research from Colombian universities suggests that enhancing entrepreneurial culture and training significantly fosters entrepreneurial attitudes (21). Finally, a new measure for entrepreneurial culture has been developed, linking it positively with nascent entrepreneurial activity.

Leadership

The influence of leadership in developing entrepreneurial ecosystems within universities is a pivotal theme in educational research. Leadership plays a critical role in nurturing a culture that supports entrepreneurship education, with an emphasis on professional development and networking (25). Challenges in guiding institutions toward entrepreneurial attitudes, including fostering trust and risk-taking, are also highlighted (26). Transformational leadership has been identified as a key factor in promoting radical entrepreneurship in public schools (27), while the necessity of strategic leadership skills and traits, such as innovation, is emphasized (28). Research shows that diverse leadership behaviors positively impact public sector entrepreneurship, particularly relation-oriented approaches (29). Additionally, the role of leadership in influencing vocational students' entrepreneurial interests has been explored, with a focus on cognitive style and networks as significant factors in entrepreneurial success (25).

Funding

Funding is a critical element in nurturing entrepreneurial and startup ecosystems within universities, as explored in various studies. Research emphasizes the need for improved credit access for small and medium enterprises (SMEs) in Albania, suggesting preferential credit schemes as a solution (30). The role of venture capitalists and financial intermediaries in entrepreneurial finance is also highlighted (31), while deeper exploration into corporate innovation finance is advocated (32). The impact of funding policies and academic-business collaboration on fostering entrepreneurship is underscored (33).

In addition, entrepreneurial orientation is linked to social performance in Spanish sports clubs, emphasizing the role of innovation (34). Studies also explore how entrepreneurial orientation influences startups' external financing decisions (35) and call for enhancements in India's funding landscape to support its startup ecosystem (36). Key drivers and challenges for startup funding in India have been identified, with crowdfunding emerging as an innovative funding source to address capital access challenges (37). A comprehensive approach is further recommended to understand crowdfunding's broader impacts on entrepreneurial ecosystems (38).

Mentorship

Mentorship is integral to fostering entrepreneurial ecosystems in academic settings, as evidenced by diverse research. Adaptable mentorship approaches tailored to an entrepreneur's personality and business stage are advocated to enhance the mentor-protégé dynamic (39). Studies by Gimmon highlight the benefits of incorporating mentorship into entrepreneurship education, suggesting that student-led mentoring programs can significantly enhance entrepreneurial skills and self-efficacy (40).

Mentorship plays a pivotal role in skills and knowledge transfer, as well as reflective learning in entrepreneurial development (15). Research emphasizes the substantial impact of entrepreneur mentors on student outcomes, particularly for those less risk-averse and from non-entrepreneurial backgrounds. Further, financial support complemented by mentorship is recommended to enhance entrepreneurial skills and build self-confidence (41). Additionally, mentorship's influence on entrepreneurial behavior is found to be indirect but significant (42).

Infrastructure

The importance of infrastructure in promoting entrepreneurial and startup ecosystems at universities is well-documented. Research highlights the greater impact of connectivity

infrastructures, such as broadband, over traditional transport facilities on startup activities, emphasizing the role of entrepreneurial learning infrastructure in spreading knowledge through codified knowledge and networks (21). The vital role of industrial infrastructure, emerging from entrepreneurial actions, in fostering innovation is also discussed (10).

The significance of resource endowments, institutional arrangements, and proprietary functions in entrepreneurship is underscored, with a particular emphasis on varied infrastructures, including ICT, in African entrepreneurial processes (43). Additionally, the interaction between private and public organizations is shown to shape infrastructure for technology entrepreneurship (44). Improved infrastructural facilities and supportive frameworks are advocated as essential components of entrepreneurship education (18).

Infrastructure development is identified as a key predictor of entrepreneurial activity, with differentiated approaches suggested to cater to specific entrepreneurial needs, such as in Taiwan's case (45). Collectively, these studies underline the multifaceted role of infrastructure in fostering innovation, entrepreneurial education, and startup success within academic ecosystems.

Innovation and Research

The intersection of research and innovation with entrepreneurial ecosystems in academic settings is pivotal for fostering entrepreneurship. The influence of local cultural contexts on innovation is emphasized, advocating for policies sensitive to these nuances (17). Research explores the intertwined yet distinct paths of innovation and entrepreneurship, highlighting their shared foundations (15). Kardos underscores the critical role of innovative small and medium enterprises (SMEs) in sustainable development and champions the entrepreneurial university model, calling for active university participation in innovation processes (46). The connection between entrepreneurship and innovation, particularly in the technology and business sectors, is well-documented (23). Enhancing students' innovative qualities and entrepreneurial abilities through scientific curricula and supportive environments is proposed as a key strategy (47). Global trends in entrepreneurship education and its role in economic growth are also explored, with a specific focus on the attitudes of UAE students towards innovation and entrepreneurship, emphasizing the need for education that reflects these perspectives (11).

A learner-centered approach in teaching entrepreneurship is advocated as crucial for stimulating innovative behaviors (48). The necessity of cross-border education integration for fostering innovation is discussed (49), along with calls for reforms in Chinese universities to cultivate innovative practices (50). Constraints in innovation and entrepreneurship education are also highlighted, emphasizing the need for universities to raise awareness and strengthen the drive for innovation among students.

Academic Regulations

Academic regulations play a pivotal role in shaping entrepreneurial ecosystems within universities, as evidenced by various studies. The restructuring of higher education governance in Hong Kong is discussed, emphasizing the need for staff engagement and curricular reforms to enhance entrepreneurship (51). The "academic enterprise" concept is introduced, linking a university's operational logic to its entrepreneurial activities (52). Singapore's biotechnology incubation centers are examined, highlighting the importance of multi-sectoral partnerships in fostering innovation (53).

Research calls for greater focus on industry-academia linkages, particularly considering disciplinary contextual differences (24). However, the absence of clear policies affecting university-industry linkages in Pakistan is noted as a significant barrier (54). Assessments of entrepreneurship education in Europe advocate for integrating high-quality practices into higher education systems (25). Additionally, entrepreneurial education and government policies are shown to influence entrepreneurial behavior significantly (55).

Experiential learning and credible lecturers are emphasized as key factors in entrepreneurship education in Ireland (56). Business incubators and government regulations are highlighted as critical components of entrepreneurship development (38). Etzkowitz further notes the evolution of university-industry linkages towards an interactive innovation model, illustrating the dynamic nature of these relationships.

Incubation

Incubation is increasingly recognized as a key driver in fostering entrepreneurial and startup ecosystems at universities and academic institutions. Integrating business incubation with entrepreneurship education is advocated as a means to enhance entrepreneurial skills, particularly in socio-economic contexts like Nigeria (57). Incubation's role in national development is emphasized, with its contributions to innovative service delivery and cross-sector collaboration being particularly noted (15, 58).

The challenges faced by European incubators, such as insufficient entrepreneurship and seed financing, are highlighted, with targeted subsidies suggested as a solution for sustainability (59). A model encompassing stimulation, education, and incubation is proposed to encourage student entrepreneurship effectively (60). Tailored incubation services and the integration of venture creation into university education are stressed as critical for fostering entrepreneurial growth (61).

Entrepreneurship education and business incubation are found to significantly impact students' entrepreneurial intentions, suggesting their combined potential in shaping future entrepreneurs (60). Advancements in entrepreneurship education are called for to meet modern economic challenges, with business incubators playing a crucial role in supporting SME growth and job creation, particularly in developing countries (62).

Entrepreneurial Education

Entrepreneurial education is increasingly recognized as a crucial driver in fostering entrepreneurial and startup ecosystems within academic institutions. Studies establish a positive correlation between entrepreneurial education and students' entrepreneurial intentions, highlighting its importance in skill development and business startup knowledge (18). Research emphasizes its impact on developing entrepreneurial alertness and mindset, which are essential for recognizing and capitalizing on business opportunities (63).

The influence of entrepreneurial education on students' self-efficacy and motivation is well-documented, with advocates calling for the integration of entrepreneurial competence into education systems (64). Variations in its impact have been identified, influenced by factors such as gender, age, cultural context, and psychological empowerment (20). Entrepreneurial education is also shown to enhance entrepreneurial intentions through attitudes, subjective norms, and perceived behavioral control (65).

The need for both formal and informal entrepreneurial education is stressed, underlining its role in mediating the relationship between entrepreneurship policy and students' willingness to engage in entrepreneurial activities (66).

Industry Linkage

The integration of academic and industry linkages is vital for fostering entrepreneurial ecosystems at universities. Ikpesu highlights the positive impact of these linkages on entrepreneurial skills among Nigerian university students, emphasizing the need for policies to strengthen university-industry partnerships (48). Research on the dynamics of these linkages in China reveals that while university technology transfer may negatively affect economic growth, startups and incumbent competitiveness exert a positive influence on entrepreneurial ecosystems (22).

The innovative performance of small and medium enterprises (SMEs) is shown to benefit significantly from external network ties and entrepreneurial orientation. Strong regional clusters are identified as critical factors that significantly impact the growth of new firms and startup employment (67). Additionally, agent-based simulations highlight the competitive nature of industrial cluster development and the importance of fostering a supportive regional entrepreneurial climate. Further studies confirm a positive correlation between external cooperation and entrepreneurial orientation in industrial clusters, underscoring the importance of collaboration for entrepreneurial success (68).

Research Gap

Despite growing institutional focus on entrepreneurship in Indian universities, current research largely examines ecosystem components such as incubation, mentorship, funding, and academic policies in isolation. This fragmented view overlooks the interdependence of these elements and their collective influence on fostering campus-based startups. Moreover, while global models offer inspiration, India's unique educational and policy landscape requires a context-specific, structured framework. There is also limited empirical analysis of how leadership

integrates and aligns these factors to drive ecosystem success. As such, a holistic understanding of the internal dynamics within Indian university startup ecosystems remains lacking. This study addresses this gap by applying Interpretative Structural Modelling (ISM) to systematically explore the relationships among ecosystem determinants and offer strategic insights for strengthening entrepreneurial environments in academic institutions.

This study aims to systematically examine the structural dynamics of the university startup ecosystem in India using Interpretative Structural Modelling (ISM). It seeks to identify and define the key enablers of entrepreneurship within academic institutions—such as incubation, mentorship, networking, funding, leadership, and academic regulations—and analyze their interdependencies. By constructing a hierarchical model that captures the internal structure and relational complexity of the ecosystem, the study provides a scalable framework for understanding how various factors interact to influence innovation outcomes. The ultimate objective is to offer context-sensitive, actionable insights to guide strategic decision-making by university administrators, policymakers, and industry stakeholders in strengthening entrepreneurial activity across Indian higher education institutions.

Methodology

The methodology of this study is designed to meticulously analyze the startup ecosystem at universities in India. It unfolds in four key phases: identifying variables, developing a Self-Structured Interaction Matrix (SSIM), conducting transitivity analysis, and determining levels of participation. Each phase plays a critical role in comprehensively understanding the interplay of factors influencing entrepreneurship at university campuses. The hierarchical approach was selected due to its capacity to model dependencies among factors influencing innovation, offering structured prioritization. Compared to flat multi-criteria decision-making (MCDM) tools, hierarchy-based models like AHP and ISM better reflect nested relationships among ecosystem components (69, 70). This is particularly effective in entrepreneurial ecosystems, where factors such as funding, mentorship, and institutional support are interdependent.

Step 1: Identifying Variables through Literature Review

The initial stage of the research is doing an extensive examination of relevant scholarly literature in order to identify key variables that are fundamental to the university startup ecosystem. This phase encompasses a wide range of scholarly and industrial sources, with a specific emphasis on identifying key factors that are essential for achieving entrepreneurial success within academic environments (71). Various key characteristics are highlighted, including Extracurricular Activities, Networks, Entrepreneurial Culture, Leadership, Funding, and numerous more. The compilation of these extensive variables provides the necessary foundation for the succeeding stages of the research.

List of Variables Identifies through literature

- Incubation (60)
- Extracurricular Activities (10)
- Networks (15)
- Entrepreneurial Culture (24)
- Funding (38)
- Mentorship (27)
- Infrastructure (59)
- Research and Innovation (30)
- Entrepreneurial Education (51)
- Industry Linkage (48)
- Leadership (69)
- Academic Regulatory Environment (24)

Step 2: Creation of Self-Structured Interaction Matrix (SSIM)

During the subsequent step, a Structural self-interaction matrix (SSIM) is produced by incorporating insights from both academic researchers and industry professionals. The matrix plays a crucial role in comprehending the interconnections and interdependencies among the variables that have been found. It provides a combination of theoretical and practical perspectives on the startup ecosystem, so enhancing our knowledge of it.

- V → row variable influences corresponding column variable
- A → row variable is influenced by corresponding column variable
- X → row and corresponding column variable influence each other

- 0 → row and corresponding column variable have no relationship

Step 3: Application of Transitivity Analysis

After the development of the Structural Similarity Index (SSIM), the technique (Figure 1) of transitivity analysis is employed. The process (Figure 1) entails the enhancement of a Structural self-interaction matrix (SSIM) in order to generate an Initial Reachability Matrix, which is subsequently advanced into a Final Reachability Matrix. This phase plays a crucial role in facilitating a more profound comprehension of the interconnections among the variables, hence emphasising the indirect as well as direct effects within the startup ecosystem.

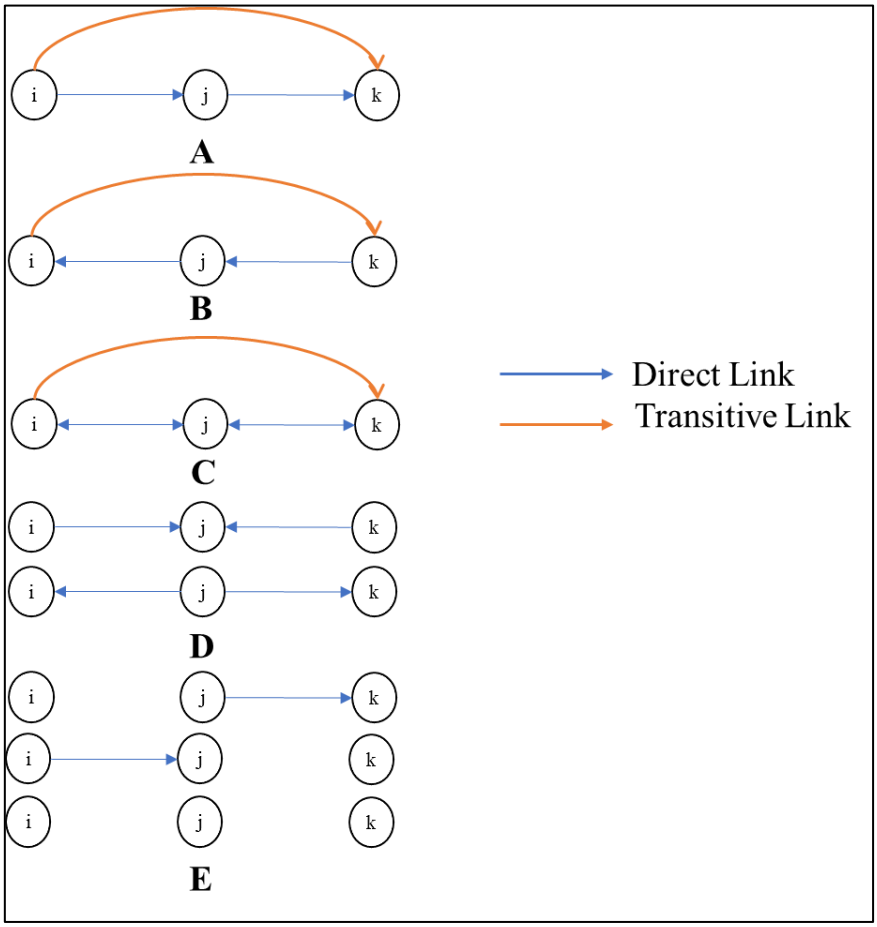

Figure 1: Transitivity Procedure

Step 4: Determining Level Participation

The final stage of the study centres on the examination of the degrees of involvement exhibited by each variable inside the startup ecosystem. The categorization of variables into distinct levels is determined based on their driving and dependent power, as indicated by the findings from the Final Reachability Matrix. The utilisation of a hierarchical structure is crucial in comprehending the intricacies of the ecosystem and the significance of each aspect in fostering a conducive environment for entrepreneurial ventures within university campuses.

The hierarchical approach resonates with layered innovation theories, such as the multilevel innovation framework and the systems of innovation theory. While these frameworks emphasize interactions across levels (individual, organizational, systemic), our method operationalizes these levels quantitatively, adding empirical robustness. However, divergence arises in the method's fixed hierarchy assumption, which may contrast with the more dynamic feedback loops suggested in complex innovation theories.

Results

Structural Self-Interaction Matrix

The Structural Self-Interaction Matrix (SSIM) within the context of Interpretive Structural Modeling serves as a schematic representation of the relationships between variables influencing entrepreneurship. Symbols such as "V", "A", "X", and "O" are utilized to signify the direction and type of influence between pairs of variables. In the matrix, Extra-Curricular Activities predominantly act as influencers, signifying their crucial role in shaping entrepreneurial aspects. Networks, reciprocally influenced by and influencing Entrepreneurial Culture, suggest a mutual reinforcement between the creation of collaborative environments and the nurturing of an entrepreneurial ethos. Entrepreneurial Culture itself is central, with bi-directional influences highlighting its core position in the entrepreneurial framework. Leadership exerts influence over multiple variables and is in turn shaped by Entrepreneurial Culture, denoting the significance of guidance in entrepreneurial development.

In the latter part of the matrix, variables such as Funding, Mentorship, Infrastructure, and Research and Innovation emerge as significant influencers, indicative of the multifaceted nature of entrepreneurial support systems. They suggest the necessity for guidance, resource availability, and innovative thought in the entrepreneurial domain. Furthermore, Governmental Academic Regulations, Incubation, and Entrepreneurial Education are influential, underscoring the impact of policy, business development environments, and educational initiatives in cultivating entrepreneurial ventures. Finally, Industry Linkage is positioned as an outcome influenced by the interplay of various factors but does not appear to reciprocate influence, potentially indicating its role as a culminating point of entrepreneurial activities rather than a contributory factor within this framework.

Table 1: Structural Self-Interaction Matrix (SSIM)

Variables	1	2	3	4	5	6	7	8	9	10	11	12
Extra-Curricular Activities		V	X	A	A	O	O	V	A	V	A	V
Networks			A	A	V	X	O	V	O	V	O	V
Entrepreneurial Culture				A	V	V	A	X	A	V	A	X
Leadership					V	V	V	V	A	V	V	V
Funding						A	V	V	A	V	V	V
Mentorship							O	V	A	V	X	X
Infrastructure								V	A	V	V	V
Research and Innovation									A	V	A	X
Academic Regulations by Govt										V	V	V
Incubation											A	A
Entrepreneurial Education												V
Industry Linkage												

The Structural Self-Interaction Matrix (SSIM, Table 1) forms the foundational input for Interpretive Structural Modeling (ISM), capturing the contextual relationships among identified entrepreneurial variables. This matrix assists in assessing the direct pairwise influence between variables such as Extra-Curricular Activities, Networks, and Leadership.

Reachability Matrix

The Reachability Matrix (Table 2 and Table 3) represents a critical step in the ISM process. In Table 2, the Initial and Final Reachability Matrices provided are integral components of an Interpretive Structural Modeling (ISM) analysis concerning entrepreneurial variables. In the Initial Matrix, the 'Driving Power' denotes the extent of a variable's influence on others, with Leadership and Academic Regulations by the Govt exhibiting the highest driving power, signifying their pivotal influence within the entrepreneurial framework. Conversely, Incubation demonstrates minimal influence, suggesting a narrower scope of impact.

Table 3 displays the Final Matrix, representing the transitive closure, reveals the inclusion of indirect influences (denoted by asterisks), thereby amplifying the 'Driving Power' for most variables. This transitivity underscores the intricacy of interdependencies, indicating a systemic interrelation where variables mutually reinforce and shape the entrepreneurial ecosystem.

Table 2: Initial Reachability Matrix

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Driving Power**
Extra-Curricular Activities	1	1	1	0	0	0	0	1	0	1	0	1	6
Networks	0	1	0	0	1	1	0	1	0	1	0	1	6
Entrepreneurial Culture	1	1	1	0	1	1	0	1	0	1	0	1	8
Leadership	1	1	1	1	1	1	1	1	0	1	1	1	11
Funding	1	0	0	0	1	0	1	1	0	1	1	1	7
Mentorship	0	1	0	0	1	1	0	1	0	1	1	1	7
Infrastructure	0	0	1	0	0	0	1	1	0	1	1	1	6
Innovation and Research	0	0	1	0	0	0	0	1	0	1	0	1	4
Academic Regulations by Govt	1	0	1	1	1	1	1	1	1	1	1	1	11
Incubation	0	0	0	0	0	0	0	0	0	1	0	0	1
Entrepreneurial Education	1	0	1	0	0	1	0	1	0	1	1	1	7
Industry Linkage	0	0	1	0	0	1	0	1	0	1	0	1	5
Dependence Power	6	5	8	2	6	7	4	11	1	12	6	11	

Table 3: Final Reachability Matrix

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Driving Power**
Extra-Curricular Activities	1	1	1	0	1*	1*	1*	1	0	1	1*	1	10
Networks	1*	1	1*	0	1	1	1*	1	0	1	1*	1	10
Entrepreneurial Culture	1	1	1	0	1	1	1*	1	0	1	1*	1	10
Leadership	1	1	1	1	1	1	1	1	0	1	1	1	11
Funding	1	1*	1*	0	1	1*	1	1	0	1	1	1	10
Mentorship	1*	1	1*	0	1	1	1*	1	0	1	1	1	10
Infrastructure	1*	1*	1	0	1*	1*	1	1	0	1	1	1	10
Innovation and Research	1*	1*	1	0	1*	1*	1*	1	0	1	1*	1	10

Academic Regulations by Govt	1	1*	1	1	1	1	1	1	1	1	1	1	12
Incubation	0	0	0	0	0	0	0	0	0	1	0	0	1
Entrepreneurial Education	1	1*	1	0	1*	1	1*	1	0	1	1	1	10
Industry Linkage	1*	1*	1	0	1*	1	1*	1	0	1	1*	1	10
Dependence Power	11	11	11	2	11	11	11	11	1	12	11	11	

Level Participation

The Level Participation analysis, summarized in Table 4, categorizes variables into hierarchical levels based on their reachability and antecedent sets. In the Interpretive Structural Modeling framework, the elements of Entrepreneurial Education and Industry Linkage occupy the foundational Level 1, indicating their role as outcomes influenced by all other factors. Extra-Curricular Activities, Networks, Entrepreneurial Culture, Funding, Mentorship, Infrastructure, Innovation and Research, and Academic Regulations by Govt are intricately connected at Level 2, suggesting a complex interplay where each element is both influencing and being influenced within the entrepreneurial ecosystem. Leadership stands out at Level 3, asserting its role as a pivotal influencer that receives inputs from the levels below but does not exert influence on the same or higher levels. Incubation is positioned at Level 4, representing a unique element that is influenced by all preceding levels but is autonomous in its level, not influencing other elements.

Table 4: Level Participation

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
2	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
3	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
4	4,	4, 9,	4,	3
5	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
6	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
7	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
8	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
9	9,	9,	9,	4
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,	10,	1
11	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2
12	1, 2, 3, 5, 6, 7, 8, 11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12,	1, 2, 3, 5, 6, 7, 8, 11, 12,	2

Conical Matrix

The Conical Matrix (Table 5) further refines this hierarchy by integrating driving and dependence powers. Incubation again emerges at Level 1, is identified as the most influenced variable, indicative of its outcome-oriented nature within the entrepreneurial process. At Level 2, Extra-Curricular Activities, Networks, Entrepreneurial Culture, Funding, Mentorship, Infrastructure, Innovation and Research, Entrepreneurial Education, and Industry Linkage demonstrate a high degree of interconnectivity and mutual influence, suggesting their collaborative and dynamic roles in shaping entrepreneurial outcomes. Leadership emerges at Level 3, acting as a directive force, while Academic Regulations by Govt at Level 4 stands as the paramount regulatory influence, shaping the entire entrepreneurial framework. To facilitate clarity, a Reduced Conical Matrix is presented in Table 6, which retains essential interrelations while simplifying the matrix layout for improved interpretability.

Table 5: Conical Matrix

Variables	10	1	2	3	5	6	7	8	11	12	4	9	Driving Power	Level
10	1	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	1	1*	1*	1*	1	1*	1	0	0	10	2
2	1	1*	1	1*	1	1	1*	1	1*	1	0	0	10	2
3	1	1	1	1	1	1	1*	1	1*	1	0	0	10	2
5	1	1	1*	1*	1	1*	1	1	1	1	0	0	10	2
6	1	1*	1	1*	1	1	1*	1	1	1	0	0	10	2
7	1	1*	1*	1	1*	1*	1	1	1	1	0	0	10	2
8	1	1*	1*	1	1*	1*	1*	1	1*	1	0	0	10	2
11	1	1	1*	1	1*	1	1*	1	1	1	0	0	10	2
12	1	1*	1*	1	1*	1	1*	1	1*	1	0	0	10	2
4	1	1	1	1	1	1	1	1	1	1	1	0	11	3
9	1	1	1*	1	1	1	1	1	1	1	1	1	12	4
Dependence Power	12	11	11	11	11	11	11	11	11	11	2	1		
Level	1	2	2	2	2	2	2	2	2	2	3	4		

Table 6: Reduced Conical Matrix

Variables	10	1	2	3	5	6	7	8	11	12	4	9	Driving Power	Level
Incubation	1	0	0	0	0	0	0	0	0	0	0	0	1	1
Extra-Curricular Activities	1	1	1	1	1*	1*	1*	1	1*	1	0	0	10	2
Networks	1	1*	1	1*	1	1	1*	1	1*	1	0	0	10	2
Entrepreneurial Culture	1	1	1	1	1	1	1*	1	1*	1	0	0	10	2
Funding	1	1	1*	1*	1	1*	1	1	1	1	0	0	10	2
Mentorship	1	1*	1	1*	1	1	1*	1	1	1	0	0	10	2
Infrastructure	1	1*	1*	1	1*	1*	1	1	1	1	0	0	10	2
Innovation and Research	1	1*	1*	1	1*	1*	1*	1	1*	1	0	0	10	2
Entrepreneurial Education	1	1	1*	1	1*	1	1*	1	1	1	0	0	10	2

Industry Linkage	1	1*	1*	1	1*	1	1*	1	1*	1	0	0	10	2
Leadership	0	1	1	1	1	1	1	1	1	1	1	0	11	3
Academic Regulations by Govt	0	0	0	0	0	0	0	0	0	0	1	1	12	4
Dependence Power	12	11	11	11	11	11	11	11	11	11	2	1		
Level	1	2	2	2	2	2	2	2	2	2	3	4		

Driving-Dependence Graph

The Driving-Dependence Graph (Figure 2) from Interpretive Structural Modelling elucidates the roles of variables within a system, classified into four quadrants by their driving and dependence powers. Quadrant II contains variables with high dependence and low driving powers, indicating their status as outcomes or resultant effects within the system. The preponderance of variables in Quadrant III with high values on both axes signifies a robust interconnectivity, implying that these factors are pivotal in influencing system dynamics and are also sensitive to external changes. The solitary variable in Quadrant IV, with high driving power, denotes a key influencer with a potential catalytic effect on the system. The absence of variables in Quadrant I suggests a system where all elements are actively interconnected, with no isolated or inert components, underscoring the integrated nature of the variables in influencing the system's behaviour.

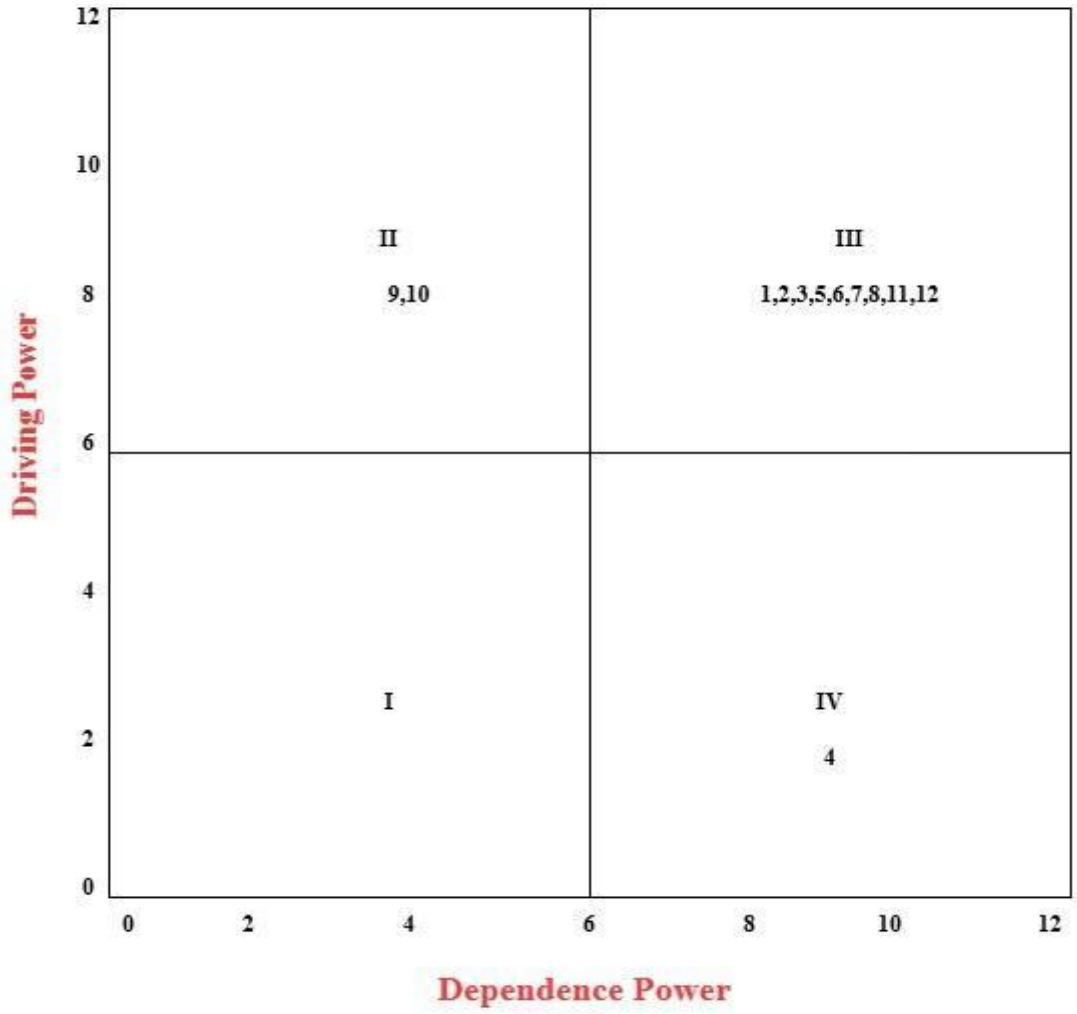

Figure 2: Driving-Dependence Graph

Hierarchical Model

The hierarchical model (Figure 3) derived from Interpretive Structural Modelling captures the systemic interactions influencing entrepreneurship. 'Incubation' forms the base, indicating its foundational role in entrepreneurial development. A subsequent level amalgamates critical factors—'Extra-Curricular Activities,' 'Networks,' 'Entrepreneurial Culture,' 'Funding,' 'Mentorship,' 'Infrastructure,' 'Innovation and Research,' 'Entrepreneurial Education,' and 'Industry Linkage'—each interdependent and pivotal for fostering an entrepreneurial milieu. 'Leadership' is positioned above this nexus, signifying its integral function in guiding and integrating the various elements of entrepreneurship. At the apex, 'Academic Regulations by Government' presides, underscoring the preeminent impact of regulatory frameworks on the entrepreneurial ecosystem. This structure elucidates the nuanced interplay of support systems, cultural dynamics, and policy environments in shaping entrepreneurial outcomes.

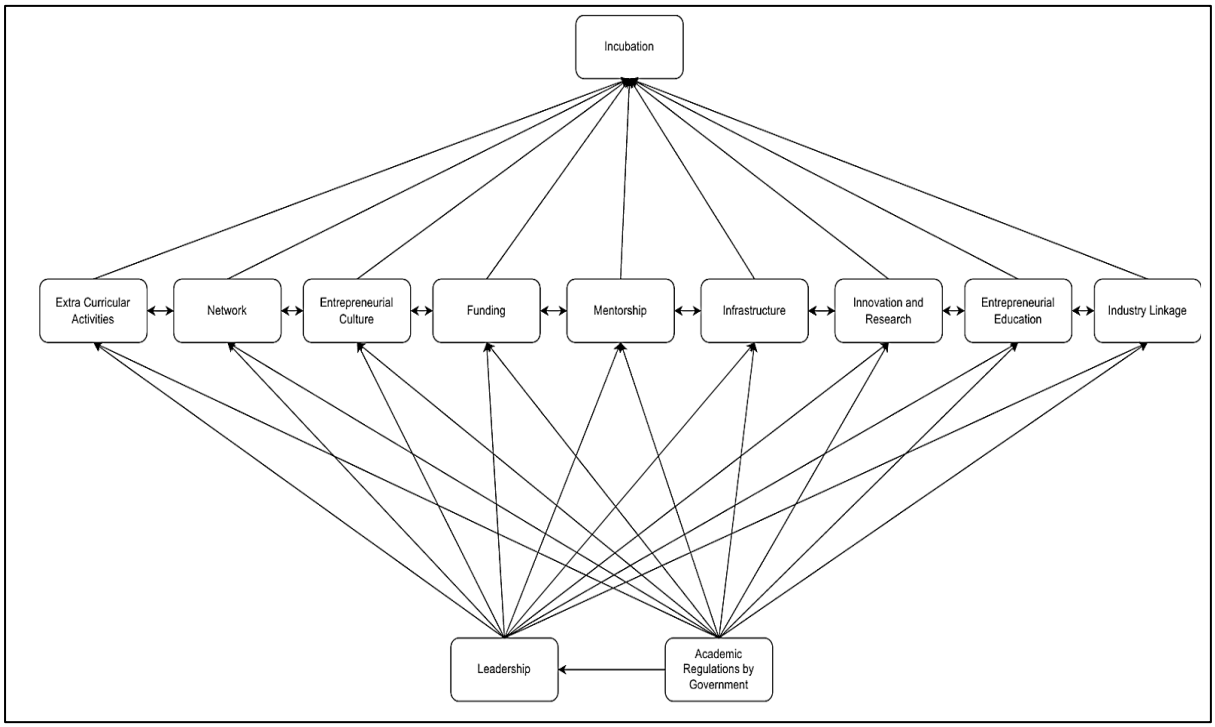

Figure 3: Hierarchical Structural Model

Discussion

The intricate interplay of factors constituting the university startup ecosystem in India has been vividly captured through the Interpretative Structural Modeling (ISM) analysis, revealing a hierarchical structure in which incubation is positioned as foundational. This finding has been supported by previous studies, where the integration of business incubation with entrepreneurship education was considered essential for skill enhancement and startup viability, particularly in socio-economically challenged contexts (57).

Furthermore, the ISM analysis has emphasized the interdependence among critical elements such as networks, entrepreneurial culture, and funding, all of which are recognized as pivotal in cultivating a thriving entrepreneurial environment. The role of extracurricular activities and networks in enhancing entrepreneurial learning and facilitating venture creation has also been acknowledged, suggesting the presence of a systemic synergy within the ecosystem (13, 15). Education institution need to revise their academic curriculum where they can embedded the innovation part is one of the success factor

Simultaneously, academic regulations have been placed at the apex of the hierarchy, highlighting the dominant influence of regulatory frameworks on the broader entrepreneurial environment. This observation has been aligned with earlier analyses that identified the significance of engaging

academic staff and reforming curricula to enhance entrepreneurial outcomes (24).

Leadership has also been identified as a central unifying element, playing a critical role in coordinating various components of the ecosystem and fostering an entrepreneurial culture (69). As Indian universities continue their efforts to promote entrepreneurship, it has become evident that a comprehensive approach is necessary one that incorporates structural enablers such as funding and mentorship, while also recognizing the deep influence of cultural and regulatory dimensions in shaping entrepreneurial success. Innovation ecosystems across India exhibit notable regional disparities, shaped by diverse economic, cultural, and institutional factors. Empirical evidence suggests that regions such as Karnataka, Gujarat, and Punjab differ significantly in terms of entrepreneurial attitudes and the strength of their supporting ecosystems (72). These differences underline the need for region-specific policy interventions to foster inclusive entrepreneurial growth.

To translate these findings into actionable strategies, universities can institutionalize dedicated innovation hubs that focus on mentorship, funding access, and interdepartmental collaboration. These centers should work in tandem with faculty and alumni networks to provide a supportive ecosystem for student ventures. Policymakers can leverage the hierarchical model to allocate resources more effectively prioritizing foundational elements like incubation and leadership development. Furthermore, industry stakeholders can contribute by offering domain-specific mentorship, access to markets, and sponsorship for campus-based innovation challenges. The structured prioritization of enablers in this study enables each stakeholder group to align efforts with system-wide needs, ensuring coherent ecosystem development.

Conclusion

The conclusion of this study highlights the nuanced architecture of the startup ecosystem within Indian universities, revealing a structured hierarchy where incubation is fundamental, serving as a springboard for entrepreneurial ventures. Leadership emerges as a cornerstone, orchestrating the integration of diverse yet interdependent elements such as funding, mentorship, and academic policies. These findings accentuate the need for a concerted strategy that embraces both structural and cultural dimensions to cultivate a thriving startup milieu.

From a managerial standpoint, the implications are multi fold. University administrators and policymakers should prioritize the establishment and support of incubators, recognizing their role in nurturing early-stage startups. To evaluate innovation success within university ecosystems, several measurable indicators can be considered. These include the number of startups incubated, patents filed, student participation in innovation challenges or hackathons, external funding attracted, industry collaborations, and the successful commercialization of student-led projects. These indicators directly correspond to key components of the hierarchical model such as incubation, mentorship, and funding. By embedding these metrics into ecosystem assessments, institutions and policymakers can better monitor progress, refine interventions, and foster sustainable innovation capacity. Furthermore, fostering a culture of entrepreneurship through mentorship programs and networking opportunities can bridge the gap between academic knowledge and practical entrepreneurial application. Funding mechanisms also require strategic alignment with the developmental phases of startups, ensuring that financial resources are accessible and tailored to the evolving needs of young enterprises. Moreover, academic regulations should be designed to encourage, rather than stifle, the entrepreneurial spirit, facilitating a more flexible and innovation-friendly educational environment.

This study culminates in a robust call to action for stakeholders within the Indian education sector, urging a critical reassessment and fortification of the startup ecosystem. Through a strategic focus on the interplay of the identified pivotal elements, there lies a substantial opportunity for India to augment its entrepreneurial output, which is quintessential for bolstering the nation's economic vitality and endurance.

Limitations and Future Research

This study is limited by the inherent subjectivity of the ISM methodology, which relies on expert input to define relationships among variables. As a result, potential bias may influence the structure of

the model. Additionally, the findings are context-specific to Indian universities and may not be directly applicable to other educational or regional settings.

Future research could enhance model validity by integrating quantitative techniques such as SEM or DEMATEL. Cross-country comparisons and longitudinal studies may also provide deeper insights into how university startup ecosystems evolve across diverse environments and over time.

Abbreviations

ECAs: Extracurricular activities, GEI: Global Entrepreneurship Index, ISM: Interpretative Structural Modelling, SSIM: Self-Structured Interaction Matrix.

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Author Contributions

Vengalarao Pachava: Conceptualization, methodology design, data analysis, manuscript drafting, and overall supervision, Correspondence and coordination with co-authors, Siva Krishna Golla: Data collection, statistical analysis, and interpretation of results, methodology and discussion, Olusiji Adebola Lasekan: Literature review, theoretical framework development, and critical revision of the manuscript for intellectual content, Afsana Salam: Literature review, Writing, editing, review of the manuscript, Sreeramulu Gosikonda: Provided contextual insights and contributed to the conclusion and recommendations section.

Conflict of Interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript. The authors declare no conflicts of interest,

Ethics Approval

This study did not involve any human or animal subjects, and ethical approval was therefore not applicable.

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